WORLD WATER DAY – 2007

Theme: Coping with Water Scarcity

SOUVENIR

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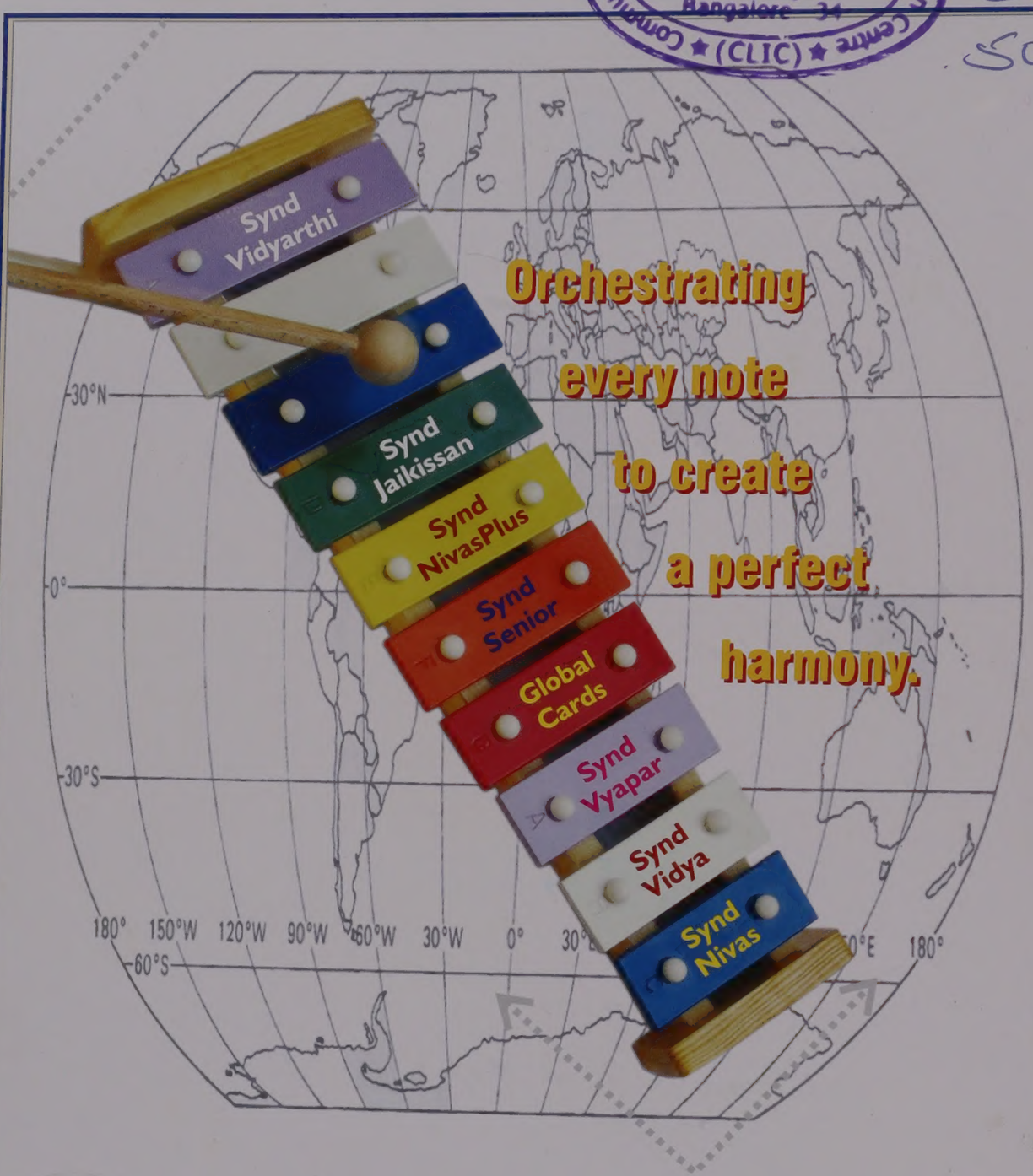

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Dr. Vasantha.

WORLD WATER DAY - 2007

THEME

"Coping with Water Scarcity"

22nd & 23rd March 2007

The Capitol Hotel

Bangalore

Organised by

BANGALORE WATER SUPPLY AND SEWERAGE BOARD

BANGALORE JALAMANDALI ABHIYANTHARARA SANGHA

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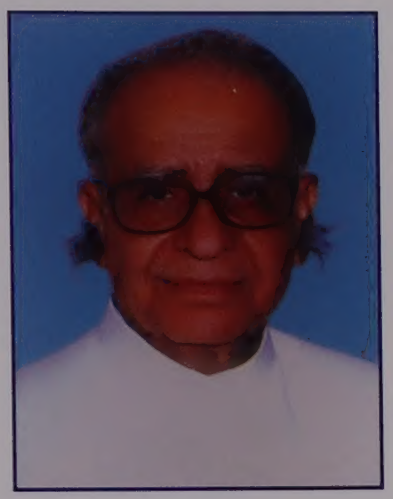

GOVERNOR
KARNATAKA

RAJ BHAVAN
BANGALORE

March 13, 2007

MESSAGE

I am glad to know that Bangalore Water Supply and Sewerage Board is organizing a two-day Seminar during March 2007 on the theme "Coping with Water Scarcity" to coincide with the World Water Day 2007.

Water resource has the potential to become an issue of global concern in the near future as the gap between demand and supply is growing at an alarming pace. The question of finding out ways and means of its replenishment has to be scientifically addressed. Recycling of the used water, rain water harvesting and conservation of available water resource are a few methods. Researchers all over the globe have been engaged in the most daunting task of finding out newer methods. A society grows only when it is able to make use of its water resources optimally keeping in mind the needs of rural and urban pockets. The need for the most judicious utilization of our water resources cannot be overemphasized. The theme of the Seminar is very relevant to the contemporary situation obtaining throughout the country. I hope the deliberations in the Seminar would be meaningful and would benefit the society.

I wish the Seminar all success.

T. N. Chaturvedi
(T.N. CHATURVEDI)

H. D. KUMARASWAMY
CHIEF MINISTER

CM/MS/548/07.

"ಸುವರ್ಣ ಕರ್ನಾಟಕ - 2006"

VIDHANA SOUDHA, BANGALORE-560 001

DATED: 13.03.2007.

MESSAGE

Future wars will be fought for water. The elixir of life is going to be the main worry of human kind in the days to come. Unfortunately mankind is still not become too concerned about the depleting water resources. It is high time that we learn to use some discretion in exploiting our water resources.

It is time we riverted back to the time tested and proven modules of water conservation. Our ancestors were wise enough to preserve forests and augment water resources by judicious use and construction of interlinked tanks and wells. They were clever enough to see that the underground water never depleted to the alarming level.

It is in this scenario that the UNITED NATIONS has declared the decade between 2005-2015 as **International Decade of Water** and March 22nd as **World Water day**. The themes for these two events "**Water for Life**" and "**Coping with Water Scarcity**" respectively stresses the importance of water and the seriousness of the problem we have to face in the days to come.

It is more appropriate that BWSSB has envisaged to celebrate **World Water Day** by organising a seminar in Bangalore in this connection. I sincerely aspire that the deliberations in this conference will be successful in finding some solutions to the problems faced by our society in managing water and water resources.

I wish the conference every success and wish that the souvenir that is going to be brought out on the occasion will shed some light on the water problems.

(H.D. Kumaraswamy)

ಎನ್.ಸಿ. ಮುನಿಯಪ್ಪ ಭಾ.ಆ.ಸೇ.
ಅಧ್ಯಕ್ಷರು
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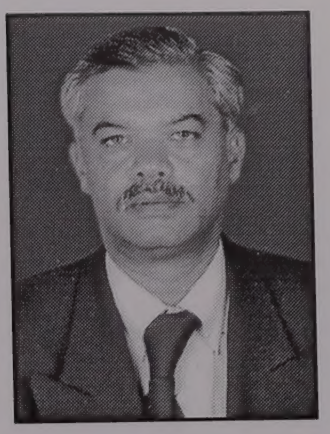
N.C. Muniyappa I.A.S.,
Chairman
Bangalore Water Supply & Sewerage Board



MESSAGE

My greetings to you on the occasion of World Water Day which is being celebrated all over the World, as always, today the 22nd March.

World supply of fresh water is finite and is threatened by pollution. Raising demand of water supply for agriculture, Industry and water supply to cities is leading competition over the allocation of fresh water resources. In many countries available fresh water resources are heavily committed and in some cases perhaps already over committed. To avoid the water crises, many countries must conserve water to manage supply and demand, pollute less and reduce environmental impact of growing population.

Under the premise that about 100 litres a day is roughly the minimum per capita requirement to meet basic household needs to maintain good health; roughly 5 to 20 time that amount is needed to satisfy the requirements of agriculture, industry, energy etc. Despite the national average of an estimated 2464 cum of water per capita per year, parts of India face water scarcity largely due to the uneven availability of water. From as high as 18417 Cum in Brahmaputra Valley, Per capita water availability comes down to a low of 411 Cum in the east flowing rivers between Pennar and Kalyakumari. Even within the Ganga basin the availability varies from 740 Cum in the Yamuna to 3379 Cum in the Gandak.

Though India receives an average rainfall equivalent to about 4000 Cubic Kilo meters, this is unevenly distributed across different parts of the country and different times of the year. The annual average per capita availability of renewable fresh water in the country fell from 5277 Cum in 1955 to 2464 Cum in 1990, which is further fallen to 2266 Cum by 1997, which gives a broad indication of the growing scarcity of water in the country. This year the theme on World Water Day "Coping With Water Scarcity" is more relevant in the prevailing situation of Bangalore, which has already exhausted fresh water resources and made situation vulnerable. I hope this seminar will discuss on the various issues of concern to BWSSB.

I wish the two day Event a grand success.

1ನೇ ಮಹಡಿ, ಕಾವೇರಿ ಭವನ, ಕೆ.ಜಿ. ರಸ್ತೆ, ಬೆಂಗಳೂರು - 560 009
1st Floor, Cauvery Bhavan, K.G Road, Bangalore - 560 009

ಬೆಂಗಳೂರು ಅಭಿವೃದ್ಧಿ ಪ್ರಾಧಿಕಾರ

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ಆಯುಕ್ತರು

ಟಿ. ಚೌಡಯ್ಯ ರಸ್ತೆ,
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14ನೇ ಮಾರ್ಚ್ 2007

ಸಂದೇಶ

ದಿನಾಂಕ 22.03.2007 ರಂದು ಬೆಂಗಳೂರು ನೀರು ಸರಬರಾಜು ಮತ್ತು ಒಳಚರಂಡಿ ಮಂಡಳಿಯು ವಿಶ್ವ ಜಲ ದಿನಾಚರಣೆಯನ್ನು ಆಚರಿಸುತ್ತಿರುವುದು ಹಾಗೂ ಈ ಸಂಬಂಧವಾಗಿ ಸಾರ್ವಜನಿಕರಲ್ಲಿ ಅರಿವು ಮೂಡಿಸುವ ಸಲುವಾಗಿ ದಿನಾಂಕ 22 ಮತ್ತು 23 ನೇ ಮಾರ್ಚ್ 2007 ರಂದು ಬೆಳಿಗ್ಗೆ ಕಾಲ್ನಡಿಗೆ ಕಾರ್ಯಕ್ರಮ ಹಾಗೂ ನಂತರ ತಾಂತ್ರಿಕ ಸಮಾವೇಶವನ್ನು ಹಮ್ಮಿಕೊಂಡಿರುವುದು ನಿಜಕ್ಕೂ ಸಂತಸದ ವಿಷಯವಾಗಿರುತ್ತದೆ.

ವಿಶ್ವ ಜಲ ದಿನಾಚರಣೆಯನ್ನು ಮೇಲ್ಕಂಡ ದಿನಗಳಿಗೆ ಸೀಮಿತಗೊಳಿಸದೇ ಪ್ರತಿ ದಿನವೂ ಆಚರಿಸುವಂತಾಗಲು ಹಾಗೂ ಈ ಸಂಬಂಧದಲ್ಲಿ ಬೆಂಗಳೂರು ಜಲಮಂಡಳಿಯು ಹಮ್ಮಿಕೊಂಡಿರುವ ಎಲ್ಲಾ ಕಾರ್ಯಕ್ರಮಗಳೂ ಯಶಸ್ವಿಯಾಗಲೆಂದು ಈ ಮೂಲಕ ಹಾರೈಸುತ್ತೇನೆ.

ಶುಭ ಹಾರೈಕೆಗಳೊಂದಿಗೆ

ಎಂ.ಕೆ.
(ಎಂ ಕೆ ಶಂಕರಲಿಂಗೇಗೌಡ) 14/3
ಆಯುಕ್ತರು
ಬೆಂಅಪ್ರಾ, ಬೆಂಗಳೂರು.

From the President's Desk

Er. G.R. Babu Kumar

Fellow Delegates,

I welcome you all to the World Water Day. At the outset, I thank Chairman, BWSSB and all my fellow Engineers CAO, FA and all others for having extended full support and co-operation in organizing this Mega event of our Associations under the aegis of BWSSB.

Even after almost 60 years of Independence access to potable water to every citizen of country looks a dream. The status of sanitation facilities is still worse and we being water professionals have a role and responsibility to help our fellow being to over come this problem.

Till the middle of last century water was not considered as a resource, nor to which any serious attention needed to be paid for the reason that water was taken for granted as inexhaustible resource, which we can tap endlessly.

Now that Urbanization is taking place at a very fast pace, the water supply status has become very pathetic, as in number of cases people get water once in 2 to 3 days to once a day for 2 to 4 hours. 24 x 7 water supply in our towns is a distant dream.

This situation clubbed with fast urbanization throws un precedented challenge to the policy makers, planners, political executive and professionals put together.

Problems related with development of safe quality supply source, its protection, conveyance, land acquisition, encroachment, metering reduction in loss and wastage, inequity in supplies, lagging modernization replacement of ongoing systems are mounting.

In this back ground role of water professional to influence on quality of life of the people by way of exhibiting high standard of competency, honesty, integrity and impartiality are very vital.

Bangalore has officially become Greater Bangalore with boundaries expanded and covering the 7 CMC's, 1 TMC and about 110 villages surrounding it. With area expanding from about 225 Sq Kms to now about 740 Sq Kms. BBMP [Bruhat Bangalore Mahanagara Palike] having come

into force has tremendous task in improving the waste management to improve the quality of civic life for a population of about 8.0 million.

We have to device ways to tackle more garbage's, more traffic to manage, more urbanization problems, related with water and sewage management, energy management coupled with population, education and growing industrial sector, mushroom growth of apartments, and gear up to civic infrastructure.

The absence of advanced planning for creation of necessary infrastructure has been at the root of the city travails.

The inclusion of mere area under Greater Bangalore will only create infrastructure problems more acute if due care is not taken to address key problem areas. This can be achieved only by making citizen participation to pave the way for a cleaner, greener and better liveable Bangalore for all.

I wish this World Water Day will be a platform to discus all the issues. The Round Table meet on urban issues at the end of technical session will address these issues, let us hope one day lets we see Singapore in Bangalore.

I wish the world water day all the best, and also thank all the Sponsor's, Advisories and well wishers for their generous contribution and Participation. I also thank all the stake holder BDA, BMP, KUWSand DB, IEI [KSC], IWWA, IPHE , BMRDA, RDPR etc., for their involvement and Mr. Thippeswamy, Retd. Chief Engineer, our Mentor and Guide and all Chief Engineers of BWSSB for their advice and support.

"Some people think in terms of Problems and some in terms of Solutions" and some Determine to make best of bad situation and you all make your own world a happier place.

Thank You all

Lets Make a World a Happier Place.
You be happy we will be Happy.

Er. G.R. Babu Kumar,
President, BJAS
Executive Engineer, BWSSB

M. N. Thippeswamy

Consultant
Chief Engineer – Supertime (Retd.), B.W.S.S.B.

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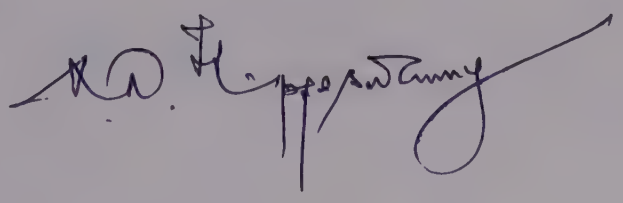
WATER SCARCITY

The point in space, or the moment in time, at which the aggregated impact of all users impinges on the supply or quality of water, under the prevailing institutions arrangements, to the extent that the total demand by all sectors, including the environment, cannot be fully satisfied.

Water use has been growing at more than twice the rate of the population increase during the last century, while the fresh water resources availability remained unchanged. Therefore, the water problem is perceived mostly as a physical "shortage" (Scarce in supply).



B.R. Nagendra
Chief Engineer (K)

Bangalore Water Supply & Sewerage Board
Cauvery Bhavan
Bangalore 560 009

Bangalore city's infrastructure is under tremendous pressure on account of unprecedented development in all fields especially in industrial, information and biotechnology and expansion of city's boundaries. This development and growth has put the infrastructure under great pressure particularly on providing basic necessity like water supply and wastewater disposal .To bridge the gap between demand and supply BWSSB has taken up water supply augmentation schemes. Implementation of these schemes in view of huge capital investment and long distance from source takes considerable time from concept to commissioning which is generally a decade. The three important issues that are serious and require immediate focused attention are bridging the gap between demand and supply, reduction of UFW, segregation of sewage and ensuring zero discharge in the storm water drain. Therefore there is a need for different approach to solve these issues These issues can be resolved by board engineers by displaying team spirit and working in a professional manner. I hope the World Water Day deliberations would through more light and focus our attention on meeting our obligations to our society and our organization.

Leena S. Nayak
Addl. Chief Engineer

Bangalore Water Supply & Sewerage Board
Cauvery Bhavan
Bangalore 560 009

I am happy to learn that Bangalore Jalamandali Abhiyantarara Sangha is celebrating World Water Day 2007 and also conducting 2 days Seminar.

I wish the event to be a grand success

WORLD WATER DAY

The international observance of World Water Day is an initiative that grew out of the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro.

The United Nations General Assembly designated 22 March of each year as the World Day for Water by adopting a resolution. This world day for water was to be observed starting in 1993, in conformity with the recommendations of the United Nations Conference on Environment and Development contained in chapter 18 (Fresh Water Resources) of Agenda 21.

States were invited to devote the Day to implement the UN recommendations and set up concrete activities as deemed appropriate in the national context.

The Subcommittee welcomes the assistance offered by IRC International Water and Sanitation Centre to contribute to an information network centre in support of the observance of the Day by Governments, as required.

WORLD WATER DAY – 2007

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Dr. S.B. Ganjigatti

2007
world water day

coping with water scarcity

challenge of the twenty-first century

UN WATER

www.worldwaterday07.org

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Introduction

22 March is World Water Day, a day for reflection and for action to address the pressing issues related to the world's water resources. Coordinated by the Food and Agriculture Organization on behalf of the 24 Agencies and Programme Members of UN-Water, World Water Day 2007 will be marked in many countries in diverse ways. The theme of World Water Day 2007 is "Coping with Water Scarcity".

Water scarcity affects all social and economic sectors and threatens the sustainability of the natural resources base. Addressing water scarcity requires an intersectoral and multidisciplinary approach to managing water resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Integration across sectors is needed. This integration needs to take into account development, supply, use and demand, and to place the emphasis on people, their livelihood and the ecosystems that sustain them. On the demand side, enhancing water productivity (the volume of production per unit of water) in all sectors is paramount to successful programmes of water scarcity alleviation. Furthermore, protecting and restoring the ecosystems that naturally capture, filter, store and release water, such as rivers, wetlands, forests and soils, is crucial to increasing the availability of water of good quality.

Experts are divided on whether the world is facing a water crisis today. Those who believe so can point with justification to the accumulation of reports throughout the world. For example, in just one week in mid-November 2006, national media sources reported local but high-profile shortages in parts of Australia, Botswana, Canada, China, Fiji, Kuwait, Liberia, Malawi, Pakistan, Philippines, South Africa, Uganda, United Arab Emirates and United States of America. Then there are the silent crises, the millions of people deprived of the water they need to live and to sustain their livelihood. It is indeed a powerful argument that a global crisis need not stem from a single cause with widespread impact alone, but rather that a crisis can be made up of many similar incidents across the globe, even if the incidents are isolated from one another.

Conscious of the increasing pressure on limited water resources, UN-Water has identified water scarcity as the theme for World Water Day 2007. This day will provide an opportunity to reflect on the challenges posed by the unsustainable increase in water use and its degradation across the globe. It will also serve as a spur to action to reverse current trends and work towards a more efficient and more equitable distribution of water for all.

The multiple dimensions of water scarcity

Water is essential for all socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users, and excessive pressure on the environment. The increasing stress on freshwater resources brought about by ever-rising demand and profligate use, as well as by growing pollution worldwide, is of serious concern.

There are several ways of defining water scarcity. In general, water scarcity is defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully. Water scarcity is a relative concept and can occur at any level of supply or demand. Scarcity may be a social construct (a product of affluence, expectations and customary behaviour) or the consequence of altered supply patterns – stemming from climate change for example. Scarcity has various causes, most capable of being remedied or alleviated. A society facing water scarcity usually has options. However, scarcity often has its roots in water shortage, and it is in the arid and semi-arid regions affected by droughts and wide climate variability, combined with high population growth and economic development, that the problems of water scarcity are most acute.

Imbalances between availability and demand, the degradation of groundwater and surface water quality, intersectoral competition, and interregional and international conflicts, all bring water issues to the fore.

Symptoms of water scarcity include severe environmental degradation (including river desiccation and pollution), declining groundwater levels, and increasing problems of water allocation where some groups win at the expense of others.

A major study, the Comprehensive Assessment of Water Management in Agriculture, reveals that one in three people today face water shortages (CA, 2007). Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers).

UN-Water

UN-Water is the mechanism coordinating the actions of the United Nations (UN) system aimed at implementing the agenda set by the Millennium Declaration and the World Summit on Sustainable Development (WSSD) in all aspects related to freshwater. UN-Water has grown out of many years of extensive collaboration and partnership among the UN Agencies. These efforts have helped to achieve significant progress and to bring water and water-related issues to the top of the political agenda. The large number of UN Agencies dealing with water reflects the multiple roles water plays in our societies and the complex interactions it implies. Advancing the implementation of sustainable water management for the benefit of all is a collective responsibility and challenge. It calls for coordinated action within the UN system and with other partners and stakeholders – including organizations from the public and private sectors, civil society and labour – as part of a global, comprehensive effort.

The main purpose of UN-Water is to complement and add value to existing programmes and projects by facilitating synergies and joint efforts in order to maximize the coherence and effectiveness of the support provided to countries pursuing the goals agreed upon by the international community. This is in line with the integrated water resources management (IWRM) approach, which calls for collaboration among all stakeholders in water management.

In most countries, the agriculture sector is the predominant consumer of water. Historically, large-scale water development projects have played a major role in poverty alleviation by providing food security, protection from flooding and drought, and expanded opportunities for employment. In many cases, irrigated agriculture has played a major role in the development of rural economies, supporting economic growth and poverty reduction. However, at the same time, poor communities have tended to suffer the greatest health burden from inadequate water supplies and, as a result of poor health, have been unable to escape from the cycle of poverty and disease. Thus, growing scarcity and competition for water stand as major threats to future advances in poverty alleviation, especially in rural areas. In semi-arid regions, increasing numbers of the rural poor are coming to see entitlement and access to water for food production, livestock and domestic purposes as more critical than access to primary health care and education.

Most countries in the Near East and North Africa suffer from acute water scarcity, as do countries such as Mexico, Pakistan, South Africa, and large parts of China and India. Irrigated agriculture represents the bulk of the demand for water in these countries. It is also usually the first sector affected by water shortage and increased scarcity, resulting in a reduced capacity to maintain per-capita food production while meeting water needs for domestic, industrial and environmental purposes. In order to sustain their needs, these countries need to focus on the efficient use of all water sources (groundwater, surface water and rainfall) and on water allocation strategies that maximize the economic and social returns to limited water resources, and at the same time enhance the water productivity of all sectors. In this endeavour, there needs to be a special focus on issues relating to equity in access to water and on the social impacts of water allocation policies.

Several factors drive the progression towards water scarcity and overallocation of water, in many cases caused by a supply-driven approach to development that does not take sufficient account of the limits of the water systems. As water becomes scarce, logics based on increased supply or a lack of understanding of the interrelations between the different sectors depending on water resources lead to increased shortages and conflicts between users. In most cases, the overriding political nature of water decisions takes precedence over the hydrological feasibility of projects, while their social consequences, in terms of deprivation of specific user groups are not well evaluated. In many places, the institutional and legal tools needed to adapt and manage water scarcity are not available, leaving the way open to abuse and inequitable access to the resource.

The appropriate scale for understanding water scarcity is at the local or regional level, notably within a river basin or sub-basin, rather than at the national or global level. In many countries, especially the larger ones, there are both water-scarce and water-abundant areas, such as in Brazil, China and Mexico. Such areas are often far away from each other with few opportunities for interbasin water transfers. Several other countries are naturally very arid within their own territory (e.g. Egypt, Niger, Mauritania, Turkmenistan) but their annual renewable freshwater resources are boosted by large perennial rivers

flowing from much wetter areas upstream (the Nile, the Niger, the Senegal and the Amu Darya rivers, respectively).

In a context of rapid change, a number of questions arise:

- How are the many competing interests involved in water being balanced?
- On what basis are decisions to be made in favour of certain developments at the expense of others?
- What are the scope and conditions for increasing water productivity in different sectors?
- Which tools should be used to enable more efficient and equitable development and allocation of water?
- How can the best use be made of the water available?
- Which measures should be put in place to protect water resources and increase water supply?
- Which institutional and legal set-ups are most appropriate for ensuring adequate coordination?
- What kind of information is needed, and how is wide public ownership of water-related problems to be ensured?

In conditions of water scarcity, the putting in place of effective and equitable management practices requires knowledge, expertise and investment at political, institutional and technical levels.

The vicious cycle of water & poverty – an issue of life & livelihood

First and foremost, water scarcity is an issue of poverty. Unclean water and lack of sanitation are the destiny of poor people across the world. Lack of hygiene affects poor children and families first, while the rest of the world's population benefits from direct access to the water they need for domestic use. One in five people in the developing world lacks access to sufficient clean water (a suggested minimum of 20 litres/day), while average water use in Europe and the United States of America ranges between 200 and 600 litres/day. In addition, the poor pay more. A recent report by the United Nations Development Programme shows that people in the slums of developing countries typically pay 5–10 times more per unit of water than do people with access to piped water (UNDP, 2006).

For poor people, water scarcity is not only about droughts or rivers running dry. Above all, it is about guaranteeing the fair and safe access they need to sustain their lives and secure their livelihoods. For the poor, scarcity is about how institutions function and how transparency and equity are guaranteed in decisions affecting their lives. It is about choices on infrastructure development and the way they are managed. In many places throughout the world, organizations struggle to distribute resources equitably.

Water for life, water for livelihood. While access to safe water and sanitation have been recognized as priority targets through the Millennium Development Goals (MDGs) and the Johannesburg plan of action of the World Summit on Sustainable Development (WSSD), there is increasing recognition that this is not enough. Millions of people rely in one way or another on water for their daily income or food production. Farmers, small rural enterprises, herders and fishing people – all need water to secure their livelihood. However, as the resources become scarce, an increasing number of them see their sources of income disappear. Silently, progressively, the number of water losers increases – at the tail end of the irrigation canal, downstream of a new dam, or as a result of excessive groundwater drawdown.

It is probably in rural areas that water scarcity affects people most. In large parts of the developing world, irrigation remains the backbone of rural economies. However, smallholder farmers make up the majority of the world's rural poor, and they often occupy marginal land and depend mainly on rainfall for production. They are highly sensitive to many changes – droughts, floods, but also shifts in market prices. However, rainwater is rarely integrated into water management strategies, which usually focus exclusively on surface water and groundwater. Countries need to integrate rainwater fully into their strategies to cope with water scarcity.

Growing demand for a finite resource

If all the freshwater on the planet were divided equally among the global population, there would be 5 000–6 000 m3 of water available for everyone, every year. As experts consider that people experience scarcity below a threshold of 1 700 m3/person, this global calculation gives an impression of abundance. However, the world's freshwater resources are distributed very unevenly, as is the world's population. The areas of most severe physical water scarcity are those where high population densities converge with low availability of freshwater. Many countries are already well below the threshold value. Jordan, like several other countries in the Near East, is an extreme case with less than 200 m3/person per year.

Central to the debate on water scarcity are the ways in which we need and use water. Water for drinking and for general household use, comparatively small in terms of volume, needs to be available in the home or, at the very least, close by. The inexorable growth of cities, concentrating large numbers of people in small areas, exacerbates this challenge locally. The water that supports ecosystems, fish, animals and invertebrates must, of course, be left to follow its natural pathways through the world's landscapes. The water that produces much of the world's energy, by hydropower generation or in cooling carbon-fired power stations, has to be available at the point of energy generation, with such decisions often dictated by factors other than water. The same is true of much of the water used in industry. However, most significant is the water that produces our food. The basic metabolism of each of our bodies – heart-beats, respiration and maintaining body temperature – requires about 1 800–2 300 kcal every day. Every calorie of the food that releases the metabolic energy within us consumes about 1 litre of water in its production.

Crop production, the process of converting carbon and water into the biomass needed to sustain our daily energy requirements, is by far the largest water-consuming sector. To produce enough food to satisfy a person's daily diet requires about 2 000–3 000 litres of water. In contrast, about 2–3 litres are required for drinking purposes, and 20–300 litres for domestic needs. As the world population continues to increase, more people will require more water for the cultivation of food, fibre and industrial crops and for livestock and fish. It is estimated that food and feed crop demand will nearly double in the coming 50 years. The two main factors driving how much more food we will need are population growth and dietary change. With rising incomes and continuing urbanization, food habits change towards richer and more varied diets – not only towards increasing consumption of staple cereals, but also leading to a shift in consumption patterns among cereal crops and away from cereals towards livestock and fish products and high-value crops that consume more water.

Agriculture accounts for more than 70 percent of the world's total water use. Its share drops to about 40 percent in countries that import food and have a developed and diverse economy, but rises to over 95 percent in many of the countries where agriculture is the primary economic activity.

Securing our food supply is not negotiable. We all need safe and good-quality food in order to live a healthy life. However, the way food is produced and the type of diet people adopt can have significant impacts on the total volume of water used in agriculture. Moreover, agricultural practices across the world have a substantial impact on the world's freshwater resources – the adoption of a clean and productive agriculture can have a positive impact on the quantity and quality of the water it uses.

Scarcity is also a question of water quality. Freshwater bodies have a limited capacity to process the pollutant charges of the effluents from expanding urban, industrial and agricultural uses. Water quality degradation can be a major cause of water scarcity.

Clearly, having 2 000 litres of water available to each of us in or near our homes every day is of little relevance to meeting our own metabolic needs. Many people are entirely isolated from food production, relying solely on purchasing food from shops or markets. Where that food is produced is fundamental to the debate on water scarcity. Countries that are wealthy enough to import food and industrial goods can typically cope well with a low national endowment of water resources. They can mobilize their limited water resources towards domestic and environmental needs – water elsewhere is used to produce the food they need.

In the last century, the world population has tripled. It is expected to rise from the present 6.5 billion to 8.9 billion by 2050, before levelling off. Water use has been growing at more than twice the rate of population increase in the last century, and, although there is no global water scarcity as such, an increasing number of regions are chronically short of water. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under conditions of water stress. The situation will be exacerbated as rapidly growing urban areas place heavy pressure on local water resources.

There will be four main drivers of increasing water scarcity during the coming decades. First, as already mentioned, there is the inexorable growth in population. Second, the world is expected to become increasingly urbanized, focusing the demand for water among an ever more concentrated population. Asian cities alone are expected to grow by 1 billion people in the next 20 years. Third, per-capita consumption, the amount of domestic water that each person uses, is expected to rise as the world becomes more developed. Fourth, while these factors will increase the demand for water, freshwater resources will change as a result of climate change. While the magnitude of this change is still subject to uncertainty and will vary from one region to another, it is recognized that semi-arid

regions will probably see an increase in the variability of precipitations, leading to more frequent periods of drought.

As farmers in particular face the challenge of accessing an increasingly scarce resource, groundwater levels are falling further each year, causing more rivers to dry up. Water is a major determinant of the health and productivity of ecosystems, placed in jeopardy in many parts of the world by reductions in water flows and water quality standards. Increasing water extraction has threatened the integrity of natural ecosystems, leading to the loss of significant biological diversity and undermining the ecosystem productivity on which so many poor people depend. Half of the world's wetlands disappeared during the twentieth century, many rivers no longer reach the sea, and fish species are endangered.

The strategic role of groundwater: In arid and semi-arid regions, where water scarcity is almost endemic, groundwater has played a major role in meeting domestic and irrigation demands. In many regions, massive use of groundwater has been practised for some time for irrigation. Groundwater mining and the lack of adequate planning, legal frameworks and governance have opened a new debate on the sustainability of the intensive use of groundwater resources.

Sharing water – a cause of conflict or an opportunity to cooperate?

Water scarcity induces competition for water between users, between sectors of the economy, and between countries and regions sharing a common resource, as is the case for international rivers. Many different interests are at stake, and equitable solutions must be found between: cities and rural areas; rich and poor; arid lands and wetlands; public and private; infrastructure and natural environments; mainstream and marginal groups; and local stakeholders and centralized authorities. Water conflicts can arise in water stressed areas among local communities and between countries because sharing a very limited and essential resource is extremely difficult. The lack of adequate legal instruments exacerbates already difficult conditions. In the absence of clear and well-established rules, chaos tends to dominate, and power plays an excessive role, leading to inequitable allocation of water. A greater focus is needed on the peaceful sharing and management of water at both international and local levels.

The fact that so many of the world's rivers and aquifers are shared by more than one country places a major emphasis on water allocation agreements. A mature debate is now emerging about sharing the benefits of water rather than focusing on agreeing national quotas of bulk water. Analysts have shown that, under the prevailing internationalist setting of the past decades, water has been a source of cooperation between nations rather than a source of conflict. There is an expectation that such cooperation will continue, and indeed that there will be greater recognition of its importance to maximizing the benefits from water within development.

Water in rural areas – issues of vulnerability and sustainability

As most of the world's poor live in rural areas, one of the most effective ways of reducing hunger and poverty is to raise their productive capacity through agricultural development. The ways forward are complex and vary from region to region, but the opportunities for increased productivity and diversification do exist and they are considerable.

Many households (about 80–90 percent of all families in rural Africa) rely upon producing and eating their own food. Already compounded by long-standing problems of land degradation and desertification, and suffering difficulties in securing inputs of fertilizer and seed, they more than others face the very real world of water scarcity. Unpredictable seasonal rains and periods of just a few days without rain at critical stages in the cropping cycle can regularly decimate their production, leading to food shortages.

Water and poverty in sub-Saharan Africa. Water development is linked closely to poverty reduction, especially in low-income countries where the economy is highly dependent on agriculture. For many African countries, bereft of alternative economic opportunities in rural areas, agriculture is viewed as the principal avenue for social development. Expectations are high that agriculture can deliver national economic growth and at the same time lift millions of households out of poverty. Along with other factors such as markets, prices, inputs and security of land tenure, water is very important to meeting these aspirations.

Irrigation is a direct source of livelihood for hundreds of millions of the rural poor in developing countries because of the food, income options and indirect benefits it generates. There are high political aspirations that agricultural development, in particular across sub-Saharan Africa, will lift many out of poverty, a few as producers of marketable products, others as wage labourers, and others in small enterprises away from the farm. The anti-poverty effects of irrigation can be assessed at two levels: production, related to the national or regional economy; and livelihoods, related to the household and its well-being (Table 1). The former has been the method traditionally used to assess irrigation impacts; conversely, a livelihood-based approach to irrigation places adequate and secure livelihood aims before increased production.

Rural farmers can be enabled to produce their own food through local soil and water conservation practices or through conservation agriculture. These are ways of farming that recognize that most poor farmers own nothing more than a hand-hoe, and make the most

of local farming conditions, providing some security against the regular shortfalls in water. Most importantly, farmers will be able to keep control over the small revenues earned within the households themselves. Critically, farmers are enabled to take that first step on the ladder towards the more commercial forms of agriculture that will create sustainable livelihoods.

TABLE 1: Livelihood-related issues for water in rural areas

Capital		Production based approach	Livelihoods based approach
Physical capital	Infrastructure for rainfed and irrigation systems.	Rainfed and irrigation farming systems improved to increase agricultural production.	Improves decision-making ability through better rainfed and irrigation farming systems. Remove risk and uncertainty including maintenance and management of natural capital stocks.
Social Capital	Community approach needed to raising or managing other forms of capital, of crucial importance in irrigation management, associations (WUA), networks	Communities mobilized to establish Water User Associations to improve agricultural water management.	Identifies poorest households and strengthen participation in, and influence on, community management systems; create safety-nets within communities to ensure the poor have access to water; improve rights to land and water and establish right to access by poor households within communities.
Natural capital	Land and water availability	Develop new and enhance existing water resources using physical and social assets.	Enhanced through training in catchment protection and maintaining natural environment.
Fianancial capital	Cash, credit, savings, animals	Develop individual or community based tariffs and charging mechanisms for water use.	Secured through access to small-scale credit.
Human capital	Labour, knowledge (through education, experience)	Train people in agricultural water management and promote gender equity.	Knowledge of demand responsive approaches, community self-assessment of needs, participatory monitoring, gender mainstreaming.

Source: UN, 2006: Chapter 7, p. 268.

Climate change – more troubled waters ahead

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The way forward – we can do much better

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Improving investments in water to reach the Millennium Development Goals

Wise use of water will be needed if all the MDGs, most of them to be reached by 2015, are to be attained. In its own right, improved access to water and sanitation is an established MDG target. In recent years, a very strong case has been made that improved access to water, sanitation and health will contribute across all of the MDGs, including targets in education and health. On World Water Day, UN-Water wishes to raise the profile of the wider contribution that must be made by water – beyond domestic water and sanitation alone – across all of the MDGs. Judicious management of increasingly scarce resources is needed if benefits in economic growth, hunger reduction, lifting households out of extreme poverty, and ensuring environmental sustainability, among others, are to be achieved. Failure to take action on water will be to the detriment of MDG attainment. With 2015 looming, now is not the time for weak governance. Worst of all, bad governance will bring with it real costs in terms of MDG attainment for millions.

Many countries are falling behind in their progress towards the specific MDG on water and, in particular, sanitation. While there are a few locations around the world where difficulties in access can be attributed to the physical scarcity of water, the overwhelming challenge is one of water governance.

Many actions are necessary to attain the MDGs that tackle poverty in ways that are entirely unconnected with water. However, water can play a key role as part of strategies for achieving most of the MDGs, including hunger reduction, universal education, empowerment of women, improved health and combating disease, environmental sustainability, and advancing a global partnership for development (Table 2). In particular, the eradication of poverty and hunger in rural areas is linked closely to fair and equitable access of the most vulnerable people to basic livelihood assets (including land and water) for domestic and productive uses. Because increased demand usually threatens the sustainability of the environment in situations of scarcity, water scarcity management is also crucial to achieving the goals of environmental sustainability.

This close relationship between MDGs and water is often not understood. Consequently, water management actions are poorly represented in the poverty reduction strategies of developing countries. Water can contribute both directly and indirectly by creating the conditions where the different goals and targets are more likely to be attained. Studies by the World Health Organization have shown that the benefits of investing in water far

outweigh the costs of making the improvements – by as much as 60 times (and never less than 3) in the major regions of the developing world.

TABLE 2:

How coping with water scarcity can affect the achieving of the Millennium Development Goals

MDG	Linkage with water scarcity
Eradicating extreme poverty and hunger	Access to water for domestic and productive uses (agriculture, industry, other economic activities), which has a direct impact on poverty and food security. Vulnerability to water-related shocks including droughts. Impact of water scarcity on both irrigated and rainfed agriculture for increased grain production; for subsistence agriculture, livestock, fish and other foods gathered in common property resources; capacity to produce cheap food with impacts on nutrition in urban and rural areas.
Achieving universal primary education	Incidence of catastrophic but often recurrent events, such as droughts, that interrupt educational attainment; drought preparedness programmes.
Promoting gender equality and empowering women	Access to water, in particular in conditions of scarce resources, with important gender-related implications, which affects the social and economic capital of women in terms of leadership, earnings and networking opportunities.
Reducing child mortality and improving maternal health	Improved nutrition and food security, which reduces susceptibility to diseases. Equitable, reliable water resources management programmes that reduce poor people's vulnerability to shocks, which in turn gives them more secure and fruitful livelihoods to draw upon in caring for their children.
Combating HIV/AIDS, malaria and other diseases	Access to water, and improved water and wastewater management in human settlements, which reduces transmission risks of mosquito-borne illnesses, such as malaria and dengue fever.
Ensuring environmental sustainability	Adequate treatment of wastewater, which contributes to less pressure on freshwater resources, helping to protect human and environmental health. Improved water management, including pollution control and water conservation, as a key factor in maintaining ecosystem functions and services.
Promoting global partnerships	Water scarcity increasingly calls for strengthened international cooperation in the fields of technologies for enhanced water productivity, financing opportunities, and an improved environment to share the benefits of scarce water management. upon in caring for their children.

Water scarcity is also linked closely to the five key areas for action identified by the UN Secretary General on the occasion of the WSSD: water, energy, health, agriculture and biodiversity. Last, it also has an impact on all the issues identified in the WSSD Johannesburg Plan of Implementation, and, in particular, on: poverty eradication; changing unsustainable consumption and production patterns; and protecting and managing the natural resources base of economic and social development.

Unlocking the potential of Africa's water for agriculture

The doubling of Africa's irrigated area is currently very high on the political agenda. Achieving this goal means that the factors that have constrained investment will need to be addressed. With less than one-third of the continent's potential under irrigation, opportunities exist across much of the continent to invest further in water for agriculture. Markets, commodity selection, ownership, land tenure, water storage for reliable supply, and international agreements on water allocations within river basins are all key factors in unlocking this potential. Many see the importance of reducing the US$18-billion food-import bill borne by the continent. Many also see the potential for boosting household incomes by creating labour opportunities. However, some recognize that, even in an optimistic scenario in which every hectare created two new jobs, the significant uplifting of 60 million households would be insufficient to make major in-roads into the extreme poverty that pervades the continent. Consequently, a dual approach is gaining ground, one in which improvements in rainfed food production for the very many vulnerable African farmers must take place alongside the seizing of viable irrigation opportunities.

Improving health through better access to water

Globally, 1.1 billion people lack access to improved water supply, and 2.6 billion are without improved sanitation. Most of these live in rural areas, but the number of urban dwellers without adequate water and sanitation services is increasing rapidly. The majority of those without adequate sanitation services live in Asia, but sub-Saharan Africa has the highest proportion of people without water. Water-related diseases, linked to inadequate access to safe water and basic sanitation, are endemic in many regions. There are 4 billion cases of diarrhoea each year, causing 2.2 million deaths (5 000 every day), mostly of children under the age of five. One million people a year, almost all under the age of five, are killed by malaria, and millions are affected by filariasis, schistosomiasis, intestinal worms and other water-related diseases. Many women suffer permanent skeletal damage from carrying heavy loads of water over long distances day after day. Poor nutrition so weakens people that they die from illnesses and infections that are not usually fatal in developed countries. The numbers of deaths and illnesses from preventable diseases are dramatic in their own right. Their impact on the economies of countries and the livelihoods of poor households is even more insidious.

Water and health are intimately linked. Water conveys pathogens to people, and provides the habitat for vectors and intermediate hosts of pathogens. Shortages of water and, above all, inadequate sanitation limit the ability of a family to cope with these threats. Worst of all, using poor quality water that is unsafe only exacerbates matters by causing further illness and infection. Diseases associated with water affect the poor in a disproportionate way, and this burden of ill health maintains the vicious cycle of poverty and sickness.

It is against this backdrop that the potential for access to improved water sources and best water management practices, basic sanitation and improved hygiene behaviour must be developed to the full. Major health gains can be achieved at household level through personal protection, whether through oral rehydration salts or the use of chlorination tablets for drinking-water. Farmers can choose options that reduce health risks and their exposure to illness without detriment to their production. Communities can mobilize to work towards improved drinking-water facilities. They can learn about drinking-water contamination risks in their homes, and about the treatment and safe storage of drinking-water from the unreliable sources upon which so many depend. Governments can take action to bring their health sectors and water managers together in successful partnerships.

Producing more with less water

Increasing water productivity holds the key to future water scarcity challenges. Without further improvements in water productivity or major shifts in production patterns, the amount of water used for agriculture, industrial and domestic activities will increase by 60–90 percent by 2050, depending on population, incomes and assumptions about water requirements for the environment. In agriculture alone, the total volume of water used in crop production would be 11 000–13 500 km3, almost double the 7 130 km3 of today. Cotton production, a high-demand agricultural practice, is projected to grow by 1.5 percent annually, and a further burden is expected to come from increased demand for biofuel. By 2030, world energy demand will rise by 50 percent, and two-thirds of this demand will come from developing countries.

However, there is scope for an accelerated increase in water productivity. Water productivity in agriculture has increased steadily in recent decades, largely owing to increasing crop yields, and the potential exists for further increase. However, the pace of such increase will vary according to the type of policies and investments put in place, with substantial variations in the impact on the environment and livelihoods of rural populations.

Targeted investments in all sectors, combined with a package of institutional measures that promote enhanced efficiency while guaranteeing equity in access to water, can do much to alleviate water scarcity and secure environmental sustainability.

Agriculture and water scarcity – imperatives for increasing water productivity at all levels

Today, agriculture accounts for 70 percent of all water use globally, up to 95 percent in several developing countries. Adding to the pressures on agricultural use is the increased awareness of the instrumental value of water in maintaining environmental services and ecosystem resilience. Increasing the efficiency of water use and enhancing agricultural water productivity at all levels of the production chains are becoming priorities in a rapidly growing number of countries. A systematic approach to agricultural water productivity requires actions at all levels, from crops to irrigation schemes, and up to national and international economic systems, including the trade in agricultural products. It calls for an informed discussion on the scope for improved water productivity in order to ameliorate intersectoral competition for water resources and optimize social and economic outcomes. To keep pace with the growing demand for food and taking into consideration an increase in water productivity, it is estimated that 14 percent more freshwater will need to be withdrawn for agricultural purposes by 2030 in order to obtain the 55 percent increase in food production needed

Integrated water resources management (IWRM) – the framework for action at local, national and regional levels

At the WSSD in Johannesburg in 2002, the international community acknowledged the importance of the water scarcity challenge by adopting the short-term target of developing "integrated water resources management and water efficiency plans by 2005, with support to developing countries, through actions at all levels." In particular, the Johannesburg Plan of Implementation calls for:

- strategies and programmes for integrated river basin, watershed and groundwater management;
- measures to improve the efficiency of water use, to reduce losses and to increase recycling of water in a way that gives priority to the satisfaction of basic human needs while preserving or restoring ecosystems and their functions;
- programmes for mitigating the effects of extreme water-related events;
- diffusion of technologies and capacity building for non-conventional water resources and conservation technologies to developing countries and regions facing water scarcity conditions or subject to drought and desertification.

While there has been progress, much remains to be done in order to develop and implement such plans. IWRM is the overall framework within which all UN-Water efforts for addressing water scarcity take place.

Managing uncertainty for the benefit of the poor

The people facing the greatest problems of water scarcity on a day-to-day basis are the many rural poor. This is especially the case for those living in marginal areas where food production is at the mercy of the vagaries of climate and where they face the consequences of weak delivery of services in water and sanitation. This is a widespread and insidious problem that also affects urban dwellers, notably in Asian cities.

Many rural households produce their own food, and in their particular case, it is essential that the 800–1 000 m3 of water per person they need to secure their annual food production is available locally on their fields. However, investments in household food security are rare and largely insufficient. Consequently, many million rural dwellers have to rely on rainfed agriculture, with all of the vagaries and vulnerabilities that accompany the unpredictability of that rain. It is this dependence on local rain for food production that make the impacts of drought so widespread and so long-lasting. Few die of thirst during drought, but very many are affected by extreme hunger for a year or more.

Enhanced economic growth is essential for poverty reduction in most parts of the world, but the quality of growth and, in particular, the extent to which it creates new opportunities for the poor also matter. Improved water management can be a catalyst for such growth. Water provides vital inputs into many productive activities and creates opportunities for local entrepreneurs in supplying technologies, constructing facilities and providing services. Local investments generate high returns and, importantly, they retain benefits in the local economy and generate significant multiplier effects. Improved water management can also be a catalyst for growth at national and regional level, where major water infrastructure investments can transform development prospects. It is essential that such investments are accompanied by effective impact assessments and proper safeguards (taking into account all the costs and benefits generated). Where this is the case, and where major infrastructure investment is accompanied by incentives that trigger private enterprise and livelihood opportunities, then water investments can play a key role in poverty reduction.

There are massive opportunities to improve the ability of poor people to lift themselves out of poverty under conditions of greater water security and sustainability. Making sure that adequate and reliable supplies of water are available for agricultural activities (including: producing the food that households grow to feed themselves and the extra they sell at markets to earn small amounts of cash; livestock; aquaculture; and horticulture) is a key to rural poverty reduction throughout the developing world. Supporting domestic water

schemes that make water available for home-based livelihood activities, such as vegetable production, pottery and laundering, is effective in targeting the poor and supporting diversified livelihoods. In many countries, broad-based agricultural growth represents the best opportunity for stimulating economic growth

Pathways for reducing poverty and vulnerability in rural areas

Ensure secure access to water for productive use for poor women and men through clarifying water rights. At the same time, address the need for redistributive policies to solve the rural poor's lack of access to assets, markets and services.

Target livelihood gains directly through small-scale, individually managed water management technologies that provide water at lower unit costs than large-scale hydraulic infrastructure and can be easily implemented locally

Acknowledge indigenous knowledge, customary laws and informal institutions in water management.

Promote multiple water-use systems – a single system for domestic use, crop production, aquaculture, agroforestry and livestock – that are effective for both reducing poverty and improving water productivity.

Protect the natural resources on which the rural poor's livelihoods depend. Fisheries, in particular, represent an important source of livelihoods and nutrition in rural areas.

Source: CA, 2007

Investments to reduce vulnerability to water-related risks and to improve agricultural productivity are compelling for environmental and equity reasons. Realizing the potential of existing rainfed areas reduces the need for water withdrawals from rivers and groundwater for new large-scale irrigation development. On the other hand, improving rainfed production also requires infrastructure, but often smaller and more distributed. Realizing this potential requires risk-mitigation measures. Water harvesting techniques are useful for bridging short dry spells, but longer dry spells may lead to crop failure. With the right incentives and measures to mitigate risks for individual farmers, improving rainfed agriculture holds considerable potential to increase food production and reduce poverty, while ensuring the maintaining of ecosystem services.

Valuing social and environmental services

As water becomes scarce, a main question today is how to best support stakeholders in managing their water demands in a context of increasing competition and interdependence. This question is especially significant for agriculture as it is the largest water user globally and faces increasing difficulty in: (i) securing a sufficient share of water resources to meet the needs of a growing world population; and (ii) managing the impacts of its activities on the resource base. Supporting stakeholders in managing their water resources means supporting them to make choices and to reach a common understanding on the necessary arrangements for sharing and allocating water-related goods and services.

Assessing and communicating the values associated with different water-related goods and services is the basis on which stakeholders have to seek a well-informed decision. This explains the growing focus on water valuation as a means to support water resources management. Water valuation means expressing the value of water-related goods and services for sharing and allocation decisions. It covers use and non-use values, extractive and in situ use values, and consumptive and non-consumptive use values. The notion of scarcity is central, and this can refer to aspects of water quantity and quality, and have both temporal and spatial dimensions.

Valuation is an increasingly important tool in the process of allocating scarce water resources. However, the indiscriminate use of a purely economic approach risks overemphasizing monetary expressions of value at the expense of environmental and social values. Valuation frameworks are needed that recognize these three dimensions and in which stakeholders play a central role. Various methods have been developed that help to express the value of water-related goods and services in quantitative, monetary units. Although potentially very useful, these methods are complicated and demanding in terms of the expertise, time and data required for their application. This hinders their widespread application, especially in developing countries. As a result, their development in the field of water valuation has been mainly academic and much more effort is needed in order to apply valuation results and processes to support water resources management and decision-making effectively.

Making water scarcity everybody's business

World Water Day 2007 is a day for raising the profile of water scarcity. Actions to cope with water scarcity are needed at various levels:

- At international level, countries need to seek increased cooperation in dealing with transboundary water management issues, within the IWRM framework, focusing on negotiations and dialogue and on the quest to optimize the overall societal benefits of water.

- At national level, policies and governance need adapting in order to better account for increased scarcity and address competing uses in a fair and equitable way. The institutional integration of water policies and increased stakeholder involvement in decision-making processes are paramount to this process, and the development of effective conflict-resolution mechanisms will become increasingly important.

- At local level, better management practices are needed in all fields, leading to increased productivity and sustainability in water use and to improved sectoral integration in the management of water resources.

The UN-Water Plan of Action "Coping with water scarcity"

A multidisciplinary approach is needed in order to consider the social, economic, cultural, legal and institutional constraints relevant to local communities, urban centres, rural areas, user groups and administrative, public and private organizations. When reconsidering development schemes at local and national level, due consideration must also be given to societal and cultural changes that induce the transformation of related water management scenarios.

Several UN Agencies have focused at length on the issues of water scarcity and have produced valuable contributions at several levels and from different perspectives. At national and local levels, many countries have developed scientific and technical knowledge, backed by policies and legislation, to prevent and remedy water scarcity impacts. There is a widespread need to share the results achieved with, and to raise awareness among, all decision-makers, managers and end users, including the general public.

The UN Agencies and Programme Members of UN-Water have identified "Coping with water scarcity" as one of its priorities for the decade "Water for life" and have developed a joint Plan of Action (PoA) to address this challenge. The primary objective of the PoA is to provide a coherent and comprehensive set of information, policy and international advice and technical support to countries and stakeholders that will enable them to address water scarcity issues more effectively at local, river basin and national levels.

Source: UN-Water, 2006

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UN. 2006. *Water, a shared responsibility. The United Nations World Water Development Report - 2.* UNESCO and Berghahn Books, Paris and London.

UNDP. 2006. Human Development Report 2006. *Beyond scarcity: Power, poverty and the global water crisis.* United Nations Development Programme, New York.

UN-Water. 2006. *Coping with water scarcity: a strategic issue and priority for system-wide action.*

Useful web sites

UN-Water: www.unwater.org

World Water Day 2007: www.worldwaterday07.org

World Water Development Report 2: www.unesco.org/water/wwap/wwdr2/

Human Development Report 2006: hdr.undp.org/hdr2006/

Rain Water Harvesting
"An Innovative Approach to Solve Water Crisis"

K.R. GOPINATH
Chairman, KRG Rain Water Foundation, Chennai

INTRODUCTION

"Water is a strange natural resource.

It can unite a community as easily as it can divide it."

"A 1-2 degree Celsius warming along with a 10-percent decrease in precipitation - well within the realm of possibility in some areas - could reduce annual runoff by 40–70 percent. Such a drop would have staggering economic and environmental consequences on regions already short of water forcing land out of irrigation, reducing hydroelectric power production, wiping out many species, and greatly constraining urban growth and the quality of life." - Intergovernmental Panel on Climate Change in the U.N. Environment Programme, held in Geneva, organized by the World Meteorological Organization.

'Rainwater Harvesting' implies nothing but conservation of rainwater. Rainwater Harvesting (RWH) is a tradition-renewed scientific technology applied to augment the groundwater both quantitatively and qualitatively. Rain Water Harvesting is a simple, economical but effective way to save rainwater for consumption and artificial recharge to solve the water problem naturally.

Water is considered the most miraculous, holy, supernatural and divine, that it has been given the name "Thirtha". The presence and absence of water clearly determine the culture and growth of a community. With the growth of economy and subsequent upgradation of the very pattern of life, there is a corresponding increase in demand for water from different sectors.

Rain is the main source of fresh water. Though India gets a high amount of rainfall, with an annual average of about 1100 mm, it is not evenly spread across the year. Most of the time, even in a year of normal rainfall, the country faces drought. It is unfortunate that we have to face the fury of the flood and the vagaries of drought year after year, in spite of the fact that India is a water rich country as per the record.

"Eminent meteorologist, Shri. P.R. PISHAROTY, points out that in most parts of the country, there is a precipitation during not more than 50 days." Even on days when rainfall does occur, it does not fall over the entire period of four hours. Heavy showers of short duration are common. Most of the places of the country therefore receive rainfall for just 100 hours in a year. The remaining 8660 hours in a year, there is no rain. Therefore, if the rain is not harvested in those 100 hours, in a year, when it falls on in those few hours, when the rivers and streams swell up, then there is little water to capture to meet human needs.

Every time it rains, only about 5-20% of the total rain is recharged into the ground depending upon the terrain, top soil condition, subsurface formation, rainfall pattern, etc. The topsoil can hold only a fraction of water that falls on it and the rest gradually percolates down, depending on the type of the soil and joins the aquifers.

The term "aquifer" may be scientifically defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to water extraction structures like open wells, bore-wells etc. The quantity of water that is recharged is much lesser than the water, which goes as run off. As huge quantity of rainwater finds its way ultimately to sea through canals and rivers, the only alternative is to **harvest and conserve this precious gift of nature by Rainwater Harvesting.**

Use of rainwater, resource of water supply, is probably the only source that will gain more and more importance in the coming years. Rainwater Harvesting is neither a costly process nor a cumbersome constructional scheme. It is neither energy intensive nor labour intensive. It can be a cost-effective alternative to other water accruing methods, such as desalination of seawater and diversion of rivers.

An added benefit of rainwater harvesting is prevention of intrusion of seawater into coastal regions. Rainwater harvesting builds inland water tables, thus thwarting any attempt by the sea to push its salty water into coastal regions and damage fresh water aquifers. Rainwater harvesting will also increase the soil moisture content which will make the soil fertile and, hence, conducive for agriculture. The conjunctive use of surface water, ground water and rainwater is the need of the hour.

Rainwater Harvesting: Solution to water scarcity

The shortage of water even for drinking has become a common phenomenon in our country. Experts opine that the major source of water, rain, must be saved and used to recharge the underground aquifer to solve the problem of water scarcity.

Not all the rainwater that falls on the earth percolates down through the topsoil. A surplus of rainwater flows out as a watercourse or as run off. The topsoil can hold only a fraction of water that falls on it and the rest slowly percolates down, depending on the kind of the soil and reaches the aquifers. "Aquifer" is defined as a formation that has saturated permeable material to yield water to water extraction structures. To avoid depletion of ground water table, the aquifers must be recharged, by making more rainwater percolate into the earth through water harvesting.

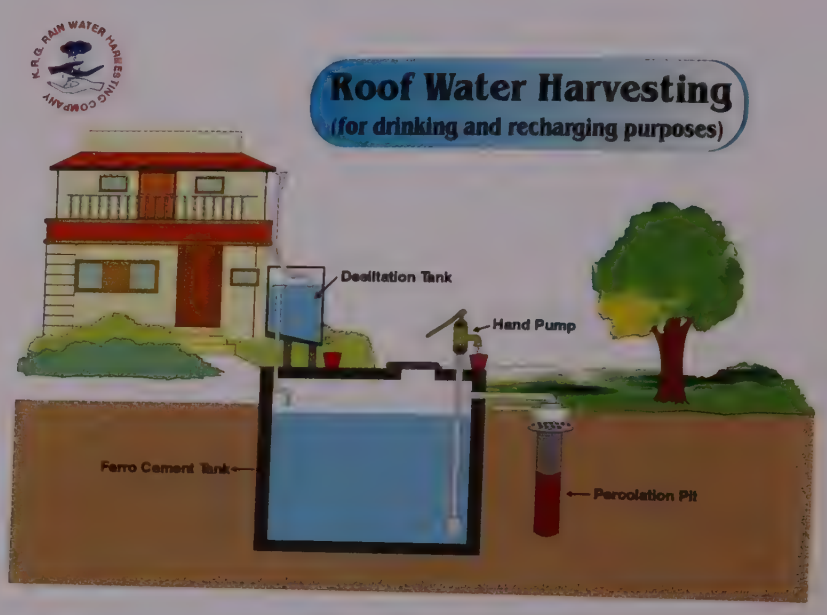
How does a rainwater-harvesting system work?

A rainwater-harvesting system runs on the principle of seepage of water into the ground. Owing to various soil features, water from rainfall is often obstructed from reaching an aquifer that is several metres underground. In the case of rainwater harvesting, water infiltrates into an aquifer through an artificial recharge structure and recharges the aquifer accordingly. Thus, rainwater falling on the surface has a smooth passage to the aquifer, where it is stored; from there it can be retrieved for future use.

Certain places do not have natural aquifers. In such cases, it is possible to construct artificial aquifers. These man-made aquifers are as effective as natural ones for the purpose of storage and retrieval of water.

Significant Methods of Rainwater Harvesting

Domestic Rainwater Collection



In the scheme, rainwater collected from roofs, courtyards and small catchment platforms can be stored in concrete sumps or High Densile polythene tank (HDP) (eg: - Sintex tank).

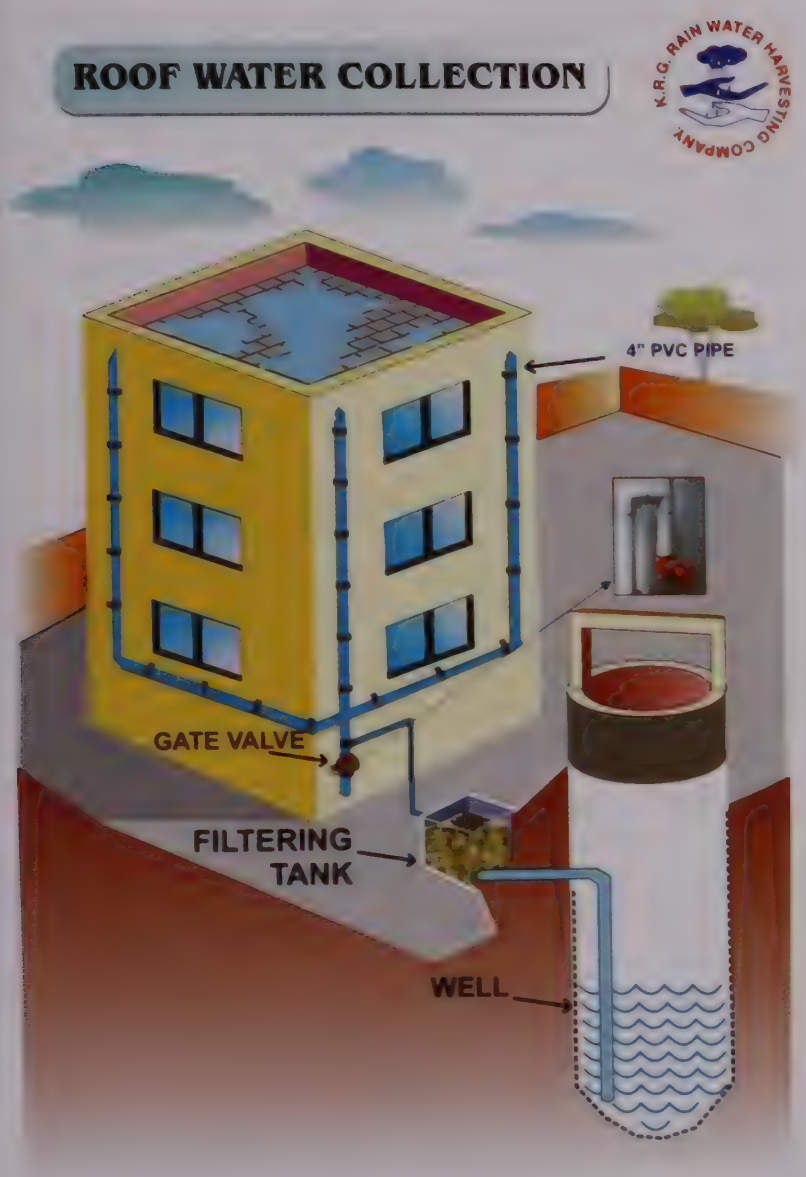
Community Rainwater Collection

The rainwater collected from terraces of buildings may be led into large size underground tanks or into

ponds. If the water is diverted to ponds located on hydrogeologically favourable zones, a production well can be constructed on downstream side of the pond to tap the water for drinking purpose.

Roof Water Harvesting

Rooftops of houses serve as relevant collection centres for rainwater. If properly diverted and used for artificial recharge roof water will augment the ground water table to a sufficient extent. The roof is connected to



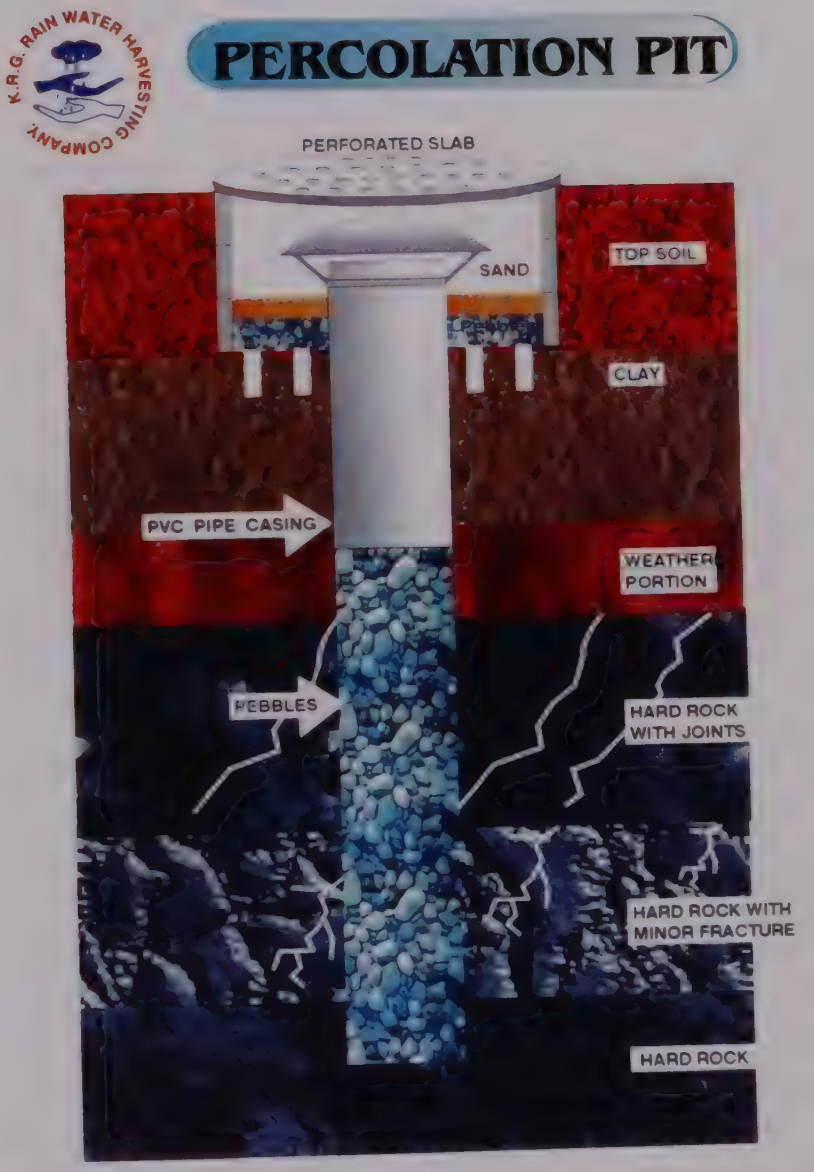
the well and the roof water is diverted through a filtering arrangement by PVC pipe.

On the basis of the fact that roof water generated initially may have some foreign materials like leaves, birds' droppings, paper clippings, etc, it is recommended to flush off the initial water at the beginning of the rainfall, which can carry off all the impurities and clean the roof through a gate valve system. It is a fact that only the first 10mm rainwater carries impurities that need to be discarded, while the rest is comparatively free from foreign elements. The roof water can be directed to a well through filtering tank containing filter media like pebbles and sand.

Based on scientific principles, it is understood that air introduced into a well during diversion of water from the roof may affect the infiltration of water. The air bubbles occupy the space in the interstices reducing the effective porosity and blocking the efficient movement of water. The bubbles are normally held tightly on to the aquifer materials and are diffused very slowly. The air clogging is easily seen by formation of air foaming when the diversion of roof water is stopped. Lowering the inlet pipe below the static water level can solve this problem in roof water harvesting.

Surface Water Harvesting

Surface water generated in open areas can be used for recharging purpose through recharge structures described below:



Percolation pits

By means of percolation pits rainwater enters into aquifer directly and easily. These structures are covered with perforated concrete slabs. Whenever the depth of clay soil is more, recharge through percolation pits with inwell bore is preferable. This inwell bore can be at the centre of the pit and is filled with pebbles and the top portion with river sand and covered with perforated concrete slab. **Depending on the lithology of the site, necessary casing has to be provided in the recharge shaft to avoid clogging.** Roof water and surface water can be diverted to percolation pits.

Dug Cum Bore Wells (DCB)

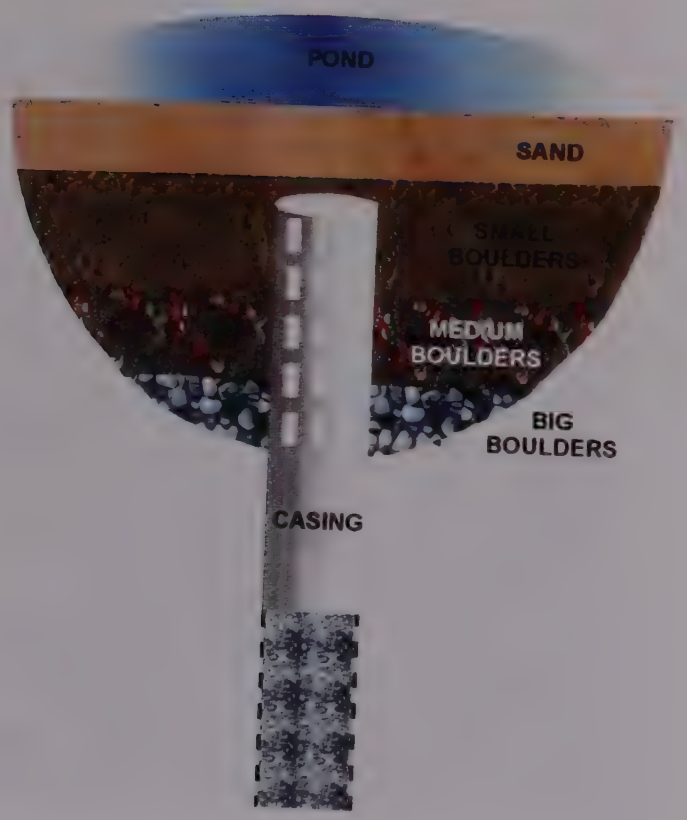
Dug cum bore well is a percolation pit with a large chamber and deeper inwell bore. Apart from filtering of recharge water through filter media, necessary coir packing can also be provided to achieve efficiency in filtering the recharge water. It is advisable to provide necessary air vent to the DCB to avoid air locking.

Mini Artificial Aquifer System (MAAS)

MAAS is ideally suitable for open areas and low-lying areas of junctions of roads, street corners, parks, stadiums, play grounds, bus terminus, theatre premises, public buildings, schools, colleges, etc.

MAAS
MINI ARTIFICIAL AQUIFER SYSTEM

K.R.G RAIN WATER HARVESTING COMPANY



In open areas, the topsoil and clayey portion of sub surface should be excavated and replaced with locally available boulders of various sizes in ascending order from the top. The top portion must be filled with coarse river sand. Two or three recharge shafts may be constructed at the bottom of the excavated portion. These recharge shafts of site-specific dimensions can be constructed penetrating through the layers of impermeable horizon to the potential aquifers. Necessary casing should also be provided to prevent clogging.

Recharging through Defunct Open Wells, Bore Wells and Hand Pumps

Depletion of ground water table dries many open wells, bore wells, and hand pumps. Several of them can be converted into favourable recharge structures. Roof water and run-off water can be diverted into these water extraction structures after filling them with pebbles and sand. Effective desilting before diverting the water into these structures is necessary.

Rainwater Harvesting through Ponds

Rainwater collected from terraces may be led into nearby ponds through pipelines for recharging the ground water aquifers. Subsequently Run-off water can be diverted into the pond after proper desilting.

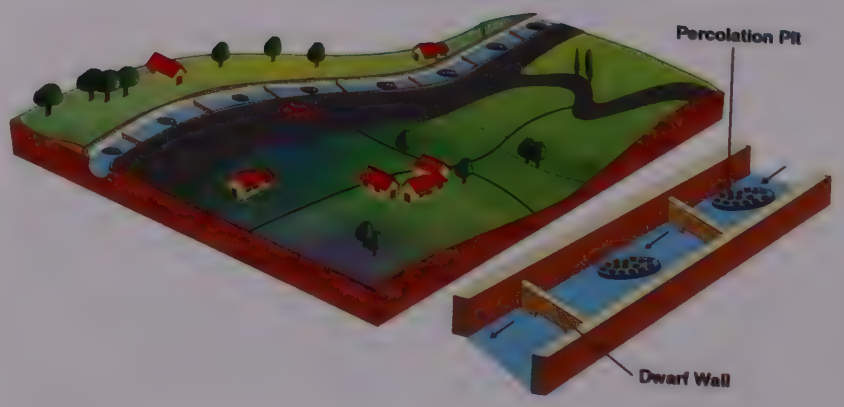
Artificial Recharge in Roads and Colonies

Enormous quantity of surface water generated during monsoon flowing through paved roads of residential colonies can be collected and made to recharge where it is generated, by constructing site-specific recharge structures on the roads itself. All the water extracting structures of colonies particularly bore wells and Hand pumps of houses on the sides of the roads are bound to give sustainable yield.

Artificial Recharge through Storm Water Drains

By constructing artificial recharge structures like percolation pits and DCB on the storm water drains or on the sides, the runoff water can be effectively used for recharge.

RECHARGE STRUCTURE FOR STORM WATER DRAIN



STRATEGIES

URBAN AREAS

It is recommended to

- Identify suitable public buildings and introduce roof top harvesting and surface water harvesting.
- Introduce water-harvesting structures on unpolluted storm water drains, open areas, parks, play grounds, etc.
- Protect aquifer sanctuaries and make it sustainable for future demand.
- Identify all water logging areas and use the stagnating water for recharging
- Store floodwater in appropriate locations.
- Introduce site-specific artificial recharge structures on important wide roads and on certain roads, which become waterways during heavily pouring monsoon days.
- Convert the numerous dry tube wells in urban areas into recharge wells.
- Make roof water harvesting a people's movement by educating the public through various means like exhibiting surface models, case studies and attractive advertisement.
- Commence consistent training programmes for concerned executives of Government and NGOs.
- Introduce water-harvesting structures on unpolluted storm water drains

RURAL AREAS

It is recommended to

- Identify suitable areas for construction of check dams, gully plugs, and dykes.
- Create mini surface water bodies like Farm Ponds, percolation ponds, flood water storage tanks, etc. in favourable areas.
- Construct under ground dykes (Bandhara) in potential river bases to check the ground water wastage and to increase the flow of water to the lands from the river.
- Identify the important unpolluted canals, which carry substantial quantity of river water and impound or harvest this water on hydro geologically potential areas.
- Build up on canal and off canal reservoirs on all canals, which carry huge, run off water.
- Develop all village ponds through processes like desilting, improving existing catchment areas and identifying new catchment areas.
- Implement innovative Mini Artificial Aquifer Systems (MAAS) on the village tanks, if desilting is not probable on economical grounds.

Land Use Planning and Ground Water Quality in a Watershed

Climatologists project that because of Global warming that the earth's temperature is expected to rise, which in turn will alter the hydrological cycle. As a result, the rainfall patterns may shift and some areas may get more rain and others less.

It may be clearly understood that the basic components involved in the hydrological cycle is the movement of water in surface, sub-surface and air. Hindrance of the movement may make a real difference in the watershed. This aspect is sadly ignored in Land use planning and hydrological cycle is being disrupted in many ways.

The manifestation of water shortage and deterioration of quality is felt in many cities and towns of India. The tremendous potential of rainwater harvesting to improve the ground water quality and quantity has been successfully proved in India. When most of the public is blissfully unaware of this unique system, the policy makers who shape the land use planning can play a significant role.

The basic components of land use planning comprise of residential colonies, commercial establishments, roads, parks, Industrial estate, junction of roads, play grounds, etc. It has become a routine and fashion for the public to pave the open areas surrounding the residences and commercial establishments. Reduced vegetative cover and less permeable soil cover increase flash run off and decrease seepage into the soil and aquifers recharge.

It is very essential that while planning land use, the recharge zone and discharge zone, the hydrogeologically potential zones, aquifer sanctuaries, wet lands, low-lying areas, elevated areas may be

identified and site specific recharge structures may be introduced.

Mini Artificial Aquifer Systems (MAAS), Recharge wells, Dug cum Bore well (DCB), Trench cum Percolation Pit (TCP), Sectorial recharge structures are a few of the artificial recharge models designed and implemented for successful contour in urban areas for surface water harvesting.

A thoughtful planning of the land use involving rainwater-harvesting techniques may find lasting solution for the sustainability and definite improvement in the quality of ground water.

It is advisable to have numerous percolation pits in agriculture lands for gradual percolation and recharging of aquifer. Construction of small bunds on slope areas slows down the run off water and helps easy percolation. Run off water can be diverted into a large well through a Baby well and filtering tank to avoid silt depositing in the well.

Depending on the terrain, geology and gradient different methods are adopted in farms and irrigation lands. This maneuver involves storing, spreading, percolating and blocking.

In gradient lands where there are slopes, construction of bunds will slow down the run off water, enabling stagnation and slow percolation. Also in areas of significant deep slopes, trenches and a series of ponds are made. In this method water is stored in ponds and the overflowing water spreads and percolates saturating the entire area.

In a rocky region a thorough study must be made to locate potential aquifers. Infiltration is possible to enhance the aquifers by recharge wells.

In a totally dry land, Sieve Plantation is adopted to convert it into a fertile land. Pitching, bunding and planting are done significantly together in this system.

On riverbeds, construction of Bandharas credibly helps enhance recharging. Bandharas are nothing but concrete walls on impermeable soil, built across the river but below the riverbed at regular intervals. These could act as underground reservoirs and recharge the surrounding area.

Rain Centre

With the idea of Mr.K.R.Gopinath and the effort of Mr. Ram Krishnan, USA, an NRI (Non resident Indian) a Rain Centre has been opened in Chennai. This is a centre open to public at free of cost for seeing and learning the working models of Rainwater harvesting, first of its kind in India, at No.4, Third Trust Link street, Mandavelipakkam, Chennai. Many people have been benefited by this centre.

Conclusion

Rainwater harvesting is not a new concept for India. Our ancestors had been turning their crises into opportunities with rainwater harvesting according to the means available then. A revolutionary attempt in water management is now essential to bring back our vanished glory through rainwater harvesting. With the highly growing demand of water, it is emphasized that rainwater harvesting should become an essential part of every home, society, panchayat, village, municipality and city in our country.

CASE STUDIES

1) Hindustan Coca-Cola Beverages Pvt. Ltd., Palakkad

KRG Rainwater Harvesting Foundation has implemented a Rainwater Harvesting system at Hindustan Coca-Cola Beverages Pvt. Ltd., Palakkad, in Kerala.

Owing to the system, at least 71,760 kilolitres of water is generated within the 37.15-acre land of the factory site every year. Before introducing the Rainwater Harvesting system, a substantially large quantity of surface water generated in the premise was rushing out without much contribution to the groundwater table of the area. It is only with the implementation of the Rainwater Harvesting system that easy natural percolation of water has become possible in the entire area.

Implementation of the Rainwater Harvesting system in the factory site included the construction of three lagoons. The combined storage capacity of the lagoons is 32,725 kilolitres. Based on the geophysical study undertaken and the hydro-geological parameters, it can be inferred that at least 50 per cent of the stored water – that is, 16,362 cubic metres – can percolate into the aquifer.

Twenty-five percolation pits have been constructed at strategic locations of the factory site for holding surface water flowing through the open area and through storm water drains. Three large-size percolation pits near the bore wells have been constructed to recharge the deeper aquifer of the bore wells.

It was identified that an enormous quantity of roof water, equivalent to 9,120 kilolitres, could be generated in a year. Now the entire amount of roof water, which was flowing out of the site, earlier, has been directed to an underground sump for further use.

Before Rainwater Harvesting, the water column in the wells was only three metres; after Rainwater Harvesting, the water column has been recorded as eight metres. The quality of water in terms of TDS before Rainwater Harvesting was 1,500 ppm; after Rainwater Harvesting, it has come down to 1,100 ppm. The yield of the bore wells has considerably increased. The quality of water has improved to a great extent, as well.

With the installation of Rainwater Harvesting structures in the factory site, significant improvement in the wells of the adjoining neighbourhood areas has been noted. Even a few days' downpour increases the water level and the yield of open wells and bore wells.

Coca-Cola Palakkad has become a model for the neighbouring villages to introduce similar Rainwater Harvesting structures to make their wells sustainable.

2) Sundram Fasteners Ltd (SFL), Padi, Chennai

SFL, Padi is totally dependent on purchased water for its entire factory, as it does not have an in-house source. It has to get water either from the CMWSSB (Chennai Metro-Water) or from tankers that supply water extracted from distant wells.

SFL spends around Rs. 3.6 million per annum towards buying of water. To bring down the expenditure, SFL assigned KRG Rainwater Harvesting Foundation the task of implementing Rainwater Harvesting in the factory site, with the work to be completed in three phases.

KRG has already implemented Phase I of the project.

Phase I involved the task of harvesting roof water, which was flowing into the drains unused.

Phase II involves the rejuvenation and recharge of an abandoned well within the SFL premises by improving its quality and yield through Rainwater Harvesting.

Phase III involves the task of collecting the entire surface run-off in the SFL site by creating an artificial pond in the northeast corner of the site.

Phase I

As mentioned earlier, the Foundation has till date implemented Phase I of the project in SFL. Thanks to the implementation, SFL was able to harvest rainwater for its use during the rains in Chennai in October and November 2002.

As part of Phase I implementation, SFL connected its entire roof area, spanning 18,000 square metres, to a storage area through pipes and rainwater collection chambers. The storage area, which is a separate rainwater-collection sump, has a capacity of 150 kilolitres. Subsequently, water is pumped from the sump to an overhead tank, from where it goes to different usage points.

Following the implementation of Phase I, SFL has succeeded in harvesting over 1,300 kilolitres of water. As a result, SFL has been able to save Rs. 52,000, due to approximately eight days of rain. The expenses for Phase I was Rs. 500,000.

The harvesting of 1,300 kilolitres of water is equivalent to the factory's five days' total water requirement. The water harvested from rain had a TDS level of 20 ppm with 7 pH value, which is purer than Metro Water and even mineral water.

Other benefits were improvement in process baths quality, lesser TDS levels in the trade effluent, sewage and hence very low TDS of treated water that is used for internal gardening.

3) Thiagarajar Mills, Madurai, Nilakottai and Virudhunagar (Tamilnadu)

Madurai, Virudhunagar and Nilakottai areas are well known for its dry weather and deep water table conditions. The mills of Thiagarajar Group situated at these locations were procuring water from external sources to meet their regular demand for most part of the year. Major portion of the rainwater was wasted as run off thereby hindering the natural percolation of water. Moreover, the presence of hard and compact rocks with in shallow depths compounded the

problems. The introduction of rainwater harvesting at these factories has improved the ground water status in terms of quantity and quality.

The following table will clearly reveal the raise in water table of the open wells after the monsoon rains. The increase in water level has been made possible and feasible due to the construction of site-specific rainwater harvesting structures constructed near the well.

Madurai

Before Rainwater Harvesting (Open Well - Madurai)	After Rainwater Harvesting (Open Well – Madurai)
Depth – 12 m	Depth – 12 m
Water Level – 9.5 m	Water Level – 2 m
Water Column – 2.5 m	Water Column – 10 m

Madurai

Before Rainwater Harvesting (Open Well - Virudhnagar)	After Rainwater Harvesting (Open Well – Virudhnagar)
Depth – 15.1 m	Depth – 15.1 m
Water Level – 14.5 m	Water Level – 4 m
Water Column – 0.6 m	Water Column – 11.1 m
Yield was moderate	Yield is good and sustainable

Nilakottai

Before Rainwater Harvesting (Open Well - Nilakottai)	After Rainwater Harvesting (Open Well – Nilakottai)
Depth – 21.8 m	Depth – 21.8 m
Water Level – 21.4 m	Water Level – 13 m
Water Column – 0.4 m	Water Column – 8.8 m
Yield was moderate	Yield is good and sustainable

The yield from the functioning bore wells has also increased considerably after installing scientifically designed rainwater harvesting structures near the bore wells. The quality of water has also improved and is well with in the limits prescribed by World Health Organization.

4) Saint Gobain Glass (India), Sriperumbudur, Tamilnadu

Saint Gobain Glass, a reputed multinational company involved in manufacturing float glass is located in SIPCOT industrial estate at Sriperumbudur, Tamilnadu. The company had installed a few surface water harvesting structures like ponds for percolating the rainwater into the substratum.

However, the company wanted to install the rainwater harvesting systems after conducting a detailed technical feasibility study. The technical feasibility study revealed the occurrence of potential aquifers at a few locations and recommendations were given to recharge these limited potential aquifers. After fruitful and thought provoking discussion with the Management of Saint Gobain, KRG Rainwater Foundation suggested a novel idea of storing the rainwater and re-use the same for regular purposes.

The roof area of the factory sheds amounts to approximately 150000 square meters, which generates around 120000 kilo litres of water per annum. A cost effective line pond designed by Prof. P. K. Aravindan, renowned structural engineer was constructed at a strategic location where maximum roof water can be collected by gradient. The combined storage capacity of the Rainwater Storage Pond, Pump House and Fire Water Tank is 54000 KL.

Beautification work has been carried out surrounding the pond and the Management boasts a beautiful and aesthetically designed rainwater harvesting structure which will serve their water needs to a major extent. The Management has invested app. 5 crores for this innovative project.

After the onset of North East monsoon in the month of October 2005, the **rainwater tank has overflowed thrice** and gives a serene atmosphere with water and greenery all around the pond.

5) At present, we the company has undertaken a mega project for **Tata Motors, and Jamshedpur Utilities and Services Co., Ltd**. Some of the prestigious projects completed recently include **Pariyaram Medical College**, Kannur (where a storage pond of capacity 1.5 crore litres has been constructed), **Ayurveda College**, Kannur, **Pepsi India Holdings**, Palakkad, **Fritolay, Pune and Hiranandani Constructions** – Powai, Thane, Andheri, Chennai. Some of the other ongoing projects include **United Breweries** – Rajasthan and Ludhiana, **Chemfab Alakalies** – Pondicherry, **Thiagarajar College**, Madurai, **Britannia Industries**, Chennai.

Other Factories

Name of the company	Before Rainwater Harvesting	After Rainwater Harvesting
i) Hiranandani Constructions, Powai, Mumba	Major portion of water drained towards the downstream lake	Rainwater impounded in recharge structures and bore wells started yielding in a sustainable manner
ii) Hiranandani Constructions, Bianca, Andheri	Quality was bad as the site is close to shore line	Good aquifer was located and recharged with roof water. Well gives sustainable yield.
Bharat Electronics Ltd., Chennai	No water in reserve	A full pond of water is in reserve
Hindustan Coca-Cola Beverages Pvt. Ltd., Bangalore	No saving of water	15,000 litres of water is saved for every two hours of rain
Hindustan Coca Cola Beverages Pvt. Ltd., Palakkad	Bought 27 tankers of water	Buys only two tankers of water
Indian Oil Corporation, Chennai	No saving of water	Several million litres of water is saved
International Flavours & Fragrances India Ltd. (Bush Boake Allen India Ltd.) Chennai	Poor water quality	Quality improved by 17 per cent within a few monthsYield has gone up by 20%.
M/s. Lucas TVS Ltd., Chennai	Moderate quality of water	TDS level of water has gone down by 17%.Yield has gone up by 20%.
Five farmers sponsored by M/s. Hindustan Coca-Cola Beverages Pvt. Ltd., Palakkad	Wells were in a dry state	TDS level of water has come down by 20%.The level of water has risen from 0.5ft to 18ft.

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Surveillance of Drinking Water Quality in Metropolis

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Abstract

Surveillance of drinking water quality (SDWQ) is the continuous and vigilant public health assessment and overview of the safety and acceptability of drinking water supply. Urban water supply scheme is an organised scheme for providing safe drinking water in adequate quantity to the consumers. The success of surveillance and monitoring programme largely depends on the well planned approach, taking into account existing surveillance activities and infrastructure, financial resources, laboratory facilities and institutional setup. The study is based on primary and secondary data collection. The water quality of raw water sources, treatment plants, distribution systems and consumer ends are assessed for physical, chemical and bacteriological parameters. All the elements of institutional setup concerned with water supply and public health aspects are assessed. The critical evaluation of primary and secondary data of existing water supply in the pre-selected metro and non-metro cities, inadequacies of the system and recommended detailed remedial measures for implementation in each case have been reported. In the present paper, surveillance of drinking water quality in metro city (Bangalore) has been highlighted.

Introduction

Water is the most basic need of mankind and is available in nature in the form of surface and groundwater. Though self-purification mechanisms like physical, chemical and microbiological processes of natural water bodies are carried out in the nature, this type of water is very rarely suitable for direct consumption. A source that is fit for consumption in the present scenario can not be expected to be always free from risk in the future; periodic water quality monitoring is necessary. Inadequate water supply compels the consumers to use available waters, often not pure for human consumption. Most often the use of polluted water without treatment, failure of treatment processes or contamination in distribution system, such problems are overlooked. Surveillance includes findings of such problems as well as undertakes remedial action to reduce or eliminate health hazards and advising on assisting with and stimulating improvements whenever possible. Surveillance programme is designed to provide an independent verification of the degree to which the water sector is meeting national and international norms for water supply.

Water Supply System

Water is one of the several resources without which a nation can not satisfy the fundamental needs of the people or achieve its important national goals and economic development. Deterioration in the quality of surface and groundwater become more likely and more critical as nation become more industrialised and urbanised and as competing demands for water increases. Commonly, little value is placed on water when it is readily available. The most common health impact of water contamination is diarrhea disease, which often results from drinking water that has been contaminated through unsafe disposal of sewage. Taking into consideration the economic importance of water and its health implications, government should promote equitable access to basic health services and safe water supplies. In particular, they should strengthen their surveillance programme to improve water quality, increase access to safe water and fight water pollution. The initiative includes the strengthening of laboratory capacity in the region and particular emphasis on improving disinfection in small systems. To improve water quality and achieve sustainable service, it is essential that decision makers and the population they represent beware of the relevant health issues concerning water and participate fully in the processes. The functioning of water supply system depends upon several unit operations and unit process. The unit operation and unit processes must

be regulated for the desirable quality of the product. If the sustained desirable quality could be assured through monitoring, there may not be any need for surveillance. However, only monitoring is not sufficient to guarantee the safety of drinking water. This has led to the concept of surveillance of drinking water quality (SDWQ).

Urban Water Schemes

Urban water supply scheme is an organised system for providing safe drinking water in adequate quantity to the consumer. The scheme has basically three components, viz., source, treatment and distribution. A variety of factors, including natural and anthropogenic, affects water supply scheme. The major issues of concern are:

- Rapid pace of urbanisation
- Deteriorating environmental conditions
- Dwindling availability of water sources
- Community culture of considering water supply as a social virtues deed
- Design of treatment plant
- Quality of service (O&M)
- Service provision, coverage and pricing policies
- Assess to water and sanitation services
- Institutional and fiscal reforms
- Policy and guidelines for private sector participation
- Sizeable investment needs
- Reliable and dependable information system and database

Surveillance of Drinking Water Quality

Water quality control involves the use of the best available technology within economic limits from protected raw water source to the required treatment and to the distribution system leading to the ultimate consumers tap. Only maintenance of standards is not sufficient to guarantee the safety of drinking water. Since the problem is multi-prolonged, the only solution to this is a continuous rigid control (surveillance) from the collection of raw water at the intake to the treatment and distribution to the "ultimate consumer". In depth studies and design of approach best fit to site specific conditions including man material management is the main objective of SDWQ. If done properly and professionally, this is the only way to guarantee that the best available technology will be used to protect the consumer in a continuously changing scientific world. SDWQ success is reachable only with the cooperation of competent and dedicated operators and public health professionals. Surveillance is designed to protect public health through the identification of action to control risks. The studies on SDWQ programme for the 23 selected cities in the country have been taken-up to ascertain the present status of drinking water quality being supplied and to evolve a suitable strategy for future planning (Figure 1). The aspects, objectives and methodology considered in undergoing the SDWQ for the selected cities are being discussed.

Figure 1: Locations of Cities/Towns Covered SDWQ Programme

Status and Programme Planning of SDWQ

A total of 26% of the studied cities, which have SDWQ programme include Bangalore. In Bangalore, the sampling frequency is once in a month. On the other hand 74% of the total cities do not undertake SDWQ programme. The SDWQ programmes for each city, thus, need be planned taking cognizance of both favourable and adverse local variations in all the

aspects and issues of surveillance and keeping the national objective of providing safe domestic water supply at the reasonable cost. Public participation and multi laboratory approach has been recommended for credibility and low budget functioning of surveillance programme.

Methodology

The study is based on the factual field data and information collected during the survey from different agencies. The steps to be followed during a surveillance study include:

- Interaction with concerned agencies responsible for O&M of water supply schemes
- Review of O&M aspects of raw water source, water treatment plants and distribution system, etc.
- Review of the existing surveillance programme
- Assessment of prevalence of water borne-diseases
- Water quality assessment through sampling and analysis of the water samples collected from raw water sources, treatment plants, main and service reservoirs and consumer ends for various physical, chemical and bacteriological parameters
- Analysis of the findings, identification of deficiencies in the existing system and suggestions of the remedial measures for brining improvements in the system.

Methodology that has been adopted for conducting surveillance of drinking water quality programme is shown in Figure 2.

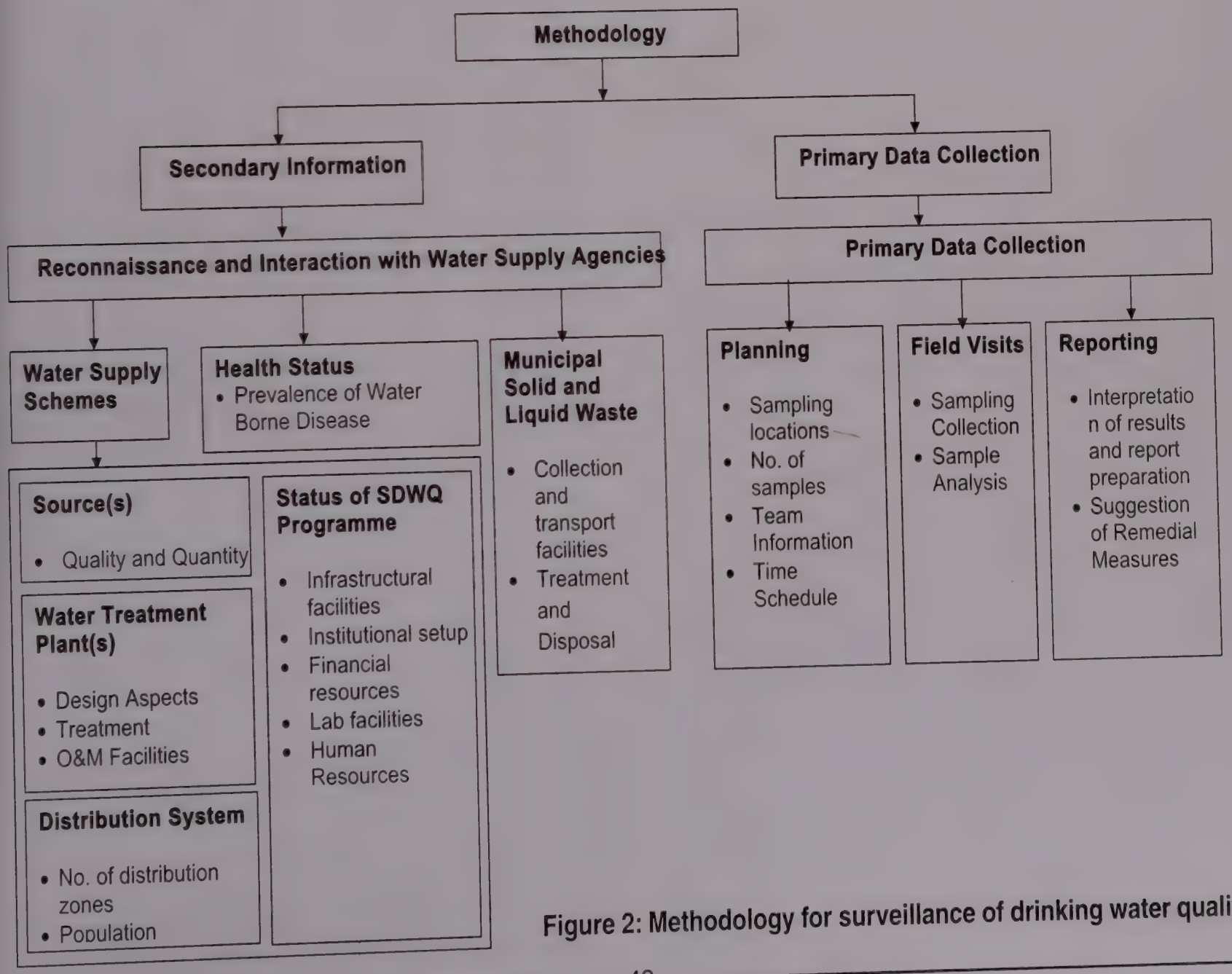

Figure 2: Methodology for surveillance of drinking water quality.

SDWQ for Bangalore

The primary and secondary information data collected during the survey have been evaluated, identified the inadequacies and deficiencies of the water supply system and delineated the suggestions for improvement. A detailed reconnaissance survey was carried out to interact with the BWSSB for the status of water supply, institutional setup and services of the city management. The details of water supply, type of water sources in organised supply, capacity of water treatment plants (WTPs) both designed and present, water distribution systems, ground water extracted, laboratory facility at central and WTP, average daily supply, leak detection and staffing pattern with their assigned work and capabilities were collected. The secondary data on the training and human resource development, organisational and financial structure, current status of existing SDWQ programme, public relations municipal solid waste generation and method of disposal, sewage management and health status in terms of water borne diseases per year was collected. Filed visits were undertaken to the raw water source, treatment plant and various units of distribution network. Sampling was done in winter, summer and monsoon seasons to collect the primary data. The samples were analysed for various physico-chemicals and bacteriological parameters to assess the quality of water at the treatment plant, clear (main) water reservoirs, service reservoirs and consumer ends. All the elements of institutional set-up concerned with water-supply and public health aspects have been assessed. The critical evaluation of existing water supply, inadequacies and deficiencies of the system has been elaborated.

Arkavathi and Cauvery Rivers are raw water sources. TK Halli and TG Halli are the sites of Water Treatment Plants. During winter the turbidity of raw water at TK Halli WTP was ranging from 3.5 to 3.8 NTU the turbidity of treated water was about 0.9 NTU. Counts for TC and FC were observed in filtered water. During summer, the turbidity of raw water ranged from 2.2 to 2.7 NTU and the treated water showed turbidity of 1.7 to 2.4 NTU. The treated water samples were found free from bacterial contamination after chlorination. During winter sampling at TG Halli WTP, the turbidity of water after filtration was between 0.92 and 3.65 NTU. During summer season turbidity of raw water varied from 8.3 to 10.3 NTU and treated water showed turbidity of 3.1 to 6.5 NTU. The treated water samples were found to be free from bacterial contamination. During monsoon raw water turbidity was in the range 11.6 – 16 NTU, while after treatment it reduced to 6.2 NTU. Counts for TC and FC were observed in treated water. The physico-chemical characteristics of treated water were within the desirable limit as per CPHEEO Guidelines. The conductivity of Cauvery water (TK Halli) increased in March during summer and was higher (465 ms/cm) than in monsoon season (151 ms/cm). Hardness, chloride, alkalinity and sulphate concentrations also increased in summer. However, the physico-chemical quality was conforming to CPHEEO Guidelines except turbidity exceeding on few occasions. Residual chlorine of 0.5 to 1 mg/L was observed and no bacterial contamination was seen.

Residual chlorine was not found in water samples of Service Reservoirs during monsoon sampling from HRBR, MNK, JP Nagar I-Phase, Kumaraswamy layout, Hosahalli. Bacterial counts for TC and FC were observed in water samples of Jaya Mahal service station, HRBR and MNK. Water quality of other service station was as per CPHEEO guidelines. The residual chlorine range was <0.1–1 mg/L at consumer ends. Residual chlorine was nil in some samples. The bacterial contamination was observed in 12 samples in monsoon. During winter sampling the residual chlorine range was 0 – 1 mg/L. Bacterial counts were observed when the residual chlorine was nil. Water quality of other service stations was as per CPHEEO guidelines.

Conclusion

People are more concerned about the quality of drinking water they receive. They are also aware of the ill effects of using contaminated water. This has led to increased interest in deploying better systems for monitoring and control of water quality. Surveillance programme should be enforced and encouraged in all cities/towns for ensuring that consumers have access to safe drinking water free from contaminants. SDWQ is the sensitive aspect of public health and preventive medicine to protect the water supply in the quest for better health. The physico-chemical quality was conforming to BIS: 10500 standards except turbidity on few occasions. Residual chlorine of 0.5 to 1 mg/L was observed in treated water from both the plants namely TK Halli and GT Halli. Treated water samples from both the plants were free from bacterial contamination during all the seasons, except one sample in the monsoon. The

water showed count for both TC and FC in Netkal, KMH and OMBR Balancing Reservoir during winter sampling. During monsoon, water samples from all the reservoirs did not show bacteriological contamination. Bacterial count for TC and FC were observed in water samples from Jaya Mahal service station, HRBR and MNK. Residual chlorine was nil in many of the reservoirs samples, during summer season. Out of 19 service stations sampled, KGT, Mount Joy, JP Nagar, Jaya Mahal and Coles service station reservoir showed bacterial contamination.

Suggestions

- Residual chlorine need be maintained at 0.5 mg/L in service reservoirs
- Excess dose of chlorine should be avoided
- Bacterial water quality of WCR and KMH need be frequently monitored and the residual chlorine of 0.5 mg/L may be maintained
- Water quality in the areas where bacterial counts were observed in repeated samples need to be monitored and improved
- Existing set-up for laboratory facilities, manpower development and water quality assessment need be improved.

Acknowledgement

The authors are grateful to Director, NEERI, Nagpur for his permission in the publication of the work.

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Selection of Liners for Structural Rehabilitation of Sewers in Tropical Climate- Indian Experience.

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Synopsis

Hydrogen sulphide induced corrosion attack in sewers in tropical climate countries is a serious matter. The deterioration of sewer assets due to corrosion attack costs millions of dollars to the city authorities. Cement based products are most vulnerable to the corrosion attack. Some countries have taken steps to use concrete pipes protected with corrosion resistant liners made of polymeric materials. Some have used corrosion resistant pipes such as vitrified clay pipes, GRP clay pipes etc in the sewer network. Some Indian cities are embarking on multi million dollar rehabilitation of sewers that have undergone structural deterioration due to hydrogen sulphide gas attack. The cities have used structural liners made of corrosion resistance polymeric materials for sewer rehabilitation and the liners used include CIPP liner, GRP liner and Spiral Wound liners. Type II standalone structural liners are often adopted to restore structural capacity of inherently weak thin walled concrete sewers used in the sewer network. The cost of liner and its installation accounts for about fifty percent of the overall cost of rehabilitation.

Introduction

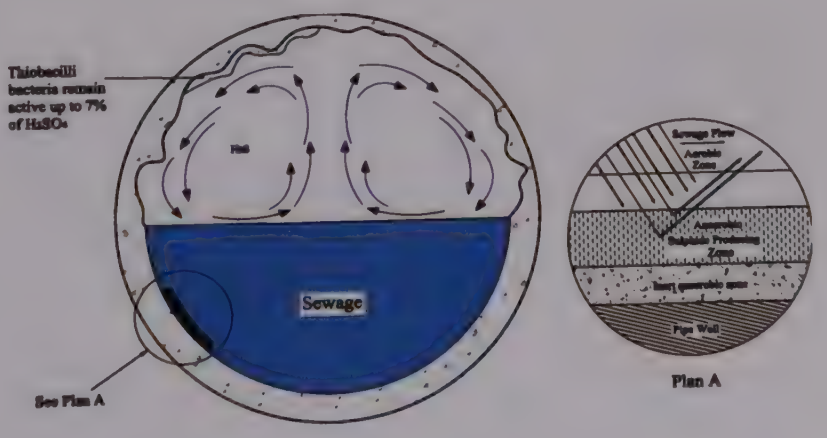
Indian metro cities have very large population as high as 14 million . Some cities have century old circular, ovoid and horseshoe shaped brick masonry sewers in the sewer network. Often they are found beneath the city's most congested and busy narrow streets. Besides, thousands of kilometres of concrete sewers were added to the city's sewer network in the past several decades to meet the needs of ever increasing population in the cities. Some of them are deep trunk sewers in the Central Business District (CBD) areas of the city.

Over the years, the corrosive conditions in sewers, notably in Mumbai, Delhi, Bangalore and other cities have caused sewers to deteriorate and become structurally weak. Added to this, most of the cities have used inherently weak NP 2 class thin walled concrete pipes for sewers till to date. Collapses of sewers due to crown corrosion is prevalent in almost all the cities.

The sewer network in Indian cities is suffering from multitude of problems ranging from hydrogen sulphide induced corrosion, leading to collapse of sewers, to inherent deficiency in pipe joints, leading to extensive leaking and heavy siltation. In some big cities, the problem has become so acute that the sewage is often by passed from the malfunctioning trunk sewers to storm water drains and waterways. The bypassed sewage thus causes serious public health hazard and pollution in drains and waterways in the cities.

Hydrogen Sulphide Induced Corrosion in Sewers

Hydrogen Sulphide is a gas that is widespread in nature. It is well-known because of its odour. Sewage contains sulphate, organic matter and bacteria and thus it has all elements required for reduction of sulphate to sulphide. The reduction of sulphate to sulphide can occur only under anaerobic conditions. The slime build-up on the submerged surfaces of the sewer wall, as illustrated in the above figure, provides anaerobic conditions for intense micro-biological action.



H₂S in Sewers in Hot Climate

The process of oxidation of hydrogen sulphide is a complex series of reactions involving many members of species Thiobacilli, each with its optimum growth rate at a given pH value. Some of the Thiobacilli can remain active in solutions containing up to 7% of H2SO4 (of pH about 0.2). The whole process of oxidation of hydrogen sulphide by bacteria and the factors which influence the bacterial corrosion of concrete in water are complex.

Why More H_2S in Sewers in Tropical Climate

H_2S is slightly heavier than air and is fairly soluble in water. At 20^0C, it can dissolve in pure water to the extent of 2.7 litres of H_2S gas per liter of water (1). The solubility decreases about 2.5% for each degree increase of temperature. Thus, in tropical climate, less H_2S could be in the form of dissolved H_2S in sewage and more H_2S is likely to escape as a gas from the sewage.

Moreover, in tropical climate the crown of the pipe is likely to have more moisture. If the surfaces are quite dry, free sulphur may be formed. But the moist conditions that prevalent in the surfaces of the sewer in tropical and hot climate countries, such as in Asian and Middle East, the species of bacteria named Thiobacillus concretivorus oxidizers H_2S to sulphuric acid by the reaction: $H_2S + 2\ O_2 = H_2SO_4$

The acid causes corrosive damages to vulnerable materials such as concrete, steel etc.

As explained in the foregoing paragraph, more and more of H_2S escapes from sewage in tropical climate which when comes in contact with moist surfaces of the sewer pipe (upper region of the sewer), where the bacteria Thiobacilli lives, will convert H_2S into H_2SO_4. It has been found that H_2SO_4 concentration up to 10% was sometime present in sewer crown in Sydney, Singapore and in Middle Eastern countries.

Corrosion of Cementitious Based Products

Cement products are susceptible to acid attack with sewage having PH value less than 5.5 (source: WRc). In colder climate, such as UK and other western countries, this condition is comparatively rare and consequently sewer corrosion is relatively less.

Countries in warmer climate such as India, and Middle East the sewer gas related corrosion in concrete products is intense and is the major contributory cause of sewer deterioration. Any cementituos bas products is extremely susceptible to hydrogen sulphi related corrosion and hence its usage witho protection shall be avoided.

Thus, the sewers in tropical climate shall be protecte from corrosion attack by lining the internal surfaces the sewer pipe with materials which are resistant corrosion by H_2SO_4 of concentration up to 10% Unless this is done the concrete sewers in tropica countries will deteriorate and fail before the expiry the design life span.

Sewers in Tropical Climate

In view of the intense H_2S induced corrosion i sewers in tropical climate, countries in Middle Eas and SE Asia have taken steps to install sewer pipes that are capable of withstanding sewer atmosphere containing high H_2S gas. Singapore has been using PVC or HDPE lined reinforced concrete pipes for mar entry size sewers (Sewer diameter greater than 900mm) since early seventies. It has also used GRP lining to protect sewage tunnels from corrosion attack. It also used various types of epoxy and PVC lining to protect structures in sewage treatment plants. In a recently completed deep trunk sewer network, Singapore used HDPE lining to protect sewage tunnels and to extend their life span to 100 years.

Singapore is now adopting vitrified clay pipes extensively for smaller diameter sewer installation. Vitrified clay pipe offers excellent resistance to H_2S induced corrosion in Sewers. Singapore has also used sewer pipe made of polycrete pipes.

Countries in Middle East have experienced very extensive H_2S induced corrosion in sewers. The countries have used a variety of pipe materials including properly engineered GRP sewer pipes, Polycrete pipes, Hobas GRP pipes, Vitrified Clay pipes etc. Australia has recently adopted the use of PVC or HDPE lined Reinforced pipes for sewers. Indian cities, such as Delhi and Bangalore would be using pipes lined with corrosion protection materials in their forthcoming projects.

Rehabilitation of Sewers in India

Based on the recent experience in rehabilitating the trunk sewers in India, it is evident that most of the trunk sewers and peripheral sewers in the network are suffering from a multitude of problems ranging from

displaced joints and leaking joints to structural deterioration of sewer body due to H_2S induced corrosion. Among the above, the structurally weak concrete pipes which have under gone H_2S induced corrosion in crown have caused serious problems to the sewer network.

Indian cities are spending multi million dollars to rehabilitate deteriorated sewers in the sewer network. The main objective of the rehabilitation is to enhance the structural durability and the hydraulic performance of the deteriorated sewers. The liners installed are often designed as standalone structural liners capable of:-

- Restoring or increasing the structural capacity of sewer.
- Protecting internal surface of the sewer from chemical and biological attack
- Providing adequate abrasion resistance to prevent structural degradation.
- Improving hydraulic performance of sewer.

Rehabilitation of Sewers in Mumbai

Bombay Municipal Corporation implemented US$40 million worth sewer rehabilitation works in 2001 to 2003 under World Bank financed projects to rehabilitate and renew city's century old ovoid brick masonry sewers and concrete sewers. The sizes of ovoid brick masonry sewers nominated for rehabilitation ranged from 2770 x 1830mm to 1140 to 760mm. Similarly the sizes of concrete sewers nominated for rehabilitation ranged from DN1050 to DN1800. Because of the shape of sewers which was predominately ovoid shape, all the bidders have opted for the use of GRP pipe liner system to rehabilitate the sewers (4).

Rehabilitation of Sewers in Delhi

Similarly, Delhi Jail Board (Delhi Water Board), implemented US$20 million worth sewer rehabilitation works to rehabilitate about 12km of malfunctioning sewers between 2003 and 2005. Delhi has about 138km of trunk sewers (of diameters greater than 900mm) and most of them require some form of rehabilitation primarily to restore or enhance their structural capacity.

Delhi Jal Board (DJB), the authority responsible for managing the water supply and sewerage facilities, is currently implementing another US$90 million worth sewer rehabilitation works to rehabilitate about 45km of sewers ranging from DN600 to DN1800. Tenders are currently underway and the rehabilitation project will be completed in 2009. DJB is also implementing another sewer rehabilitation project at a project cost US$20 million to rehabilitate a 12 km long major trunk sewer under JBIC funds.

In another US$20 million worth sewer rehabilitation works, completed in 2003 to 2005, DJB has used CIPP lining system to rehabilitate sewers of diameters from 1200mm to 1900mm. It was indeed a very challenging task for the contractors who carried out CIPP lining for sewers of this size and nature for the first time in India (an experimental lining of sewer by CIPP in Mumbai was carried out in 1995)

Sewer Rehabilitation in Bangalore

Similarly, Bangalore Water supply and Sewerage Board (BWSSB) implementing a US$40 million worth sewer refurbishment works to restore nearly 100km of trunks sewers. BWSSB has opted to rehabilitate the sewers by reconstructing them as the sewers are badly deteriorated and undersized.

Design of Liners

There are a number of liner systems available on the market for rehabilitation of deteriorated sewers. Indian cities have used Cured in Place Pipe (CIPP) and Glass fibre Reinforced Plastic (GRP) and Spiral Wound liner systems for structural restoration of sewers. The liner's ability to resist sewage gas related corrosion in sewers and abrasion resistance to withstand silt migration and movement of maintenance equipment during the service life of the sewers have also been taken into consideration during the selection and design of liners.

Type I Design

In Type 1 Design, the lining is bonded through annulus grouting to the sewer wall so that the liner, grout and the sewer body act as a rigid composite section, capable of carrying all hydraulic, ground and surface loadings

In the case of brick masonry sewer, the bricks in the sewer body would still have its inherent structural capacity. It is the jointing and the cement plastering that would have deteriorated due to hydrogen sulphide induced corrosion .

Thus it makes sense to take advantage of the inherent structural capacity contained in the bricks through the liner system. In such circumstances, it may be economically and technically attractive to adopt Type 1 Design so that the brick body and the liner would be bonded through annulus grouting to make the brick body, grout and the liner to act as a composite rigid structure to give the desired structural capacity.

However in the case of concrete sewer body which is declared as fully deteriorated, the inherent structural capacity is no longer available and hence it does not make sense to utilize the deteriorated RCC sewer body in the liner design

Type II Lining:

There are two type of Type II lining Designs. They are

(a) Type II (Hydraulic)

(b) Type II (Standalone)

Type II Design (Hydraulic)

In Type II (Hydraulic) The liner is designed to take hydraulic loadings only. Thus the liner design is suitable for the sewer when the sewer body is still capable of carrying the physical loads above the sewer. This type of sewer body is classified as "Intact". In this design, buckling of the liner is critical and the hydraulic head is usually determined from the buckling design point of view. Flexible design method is used in the design of the liner.

Type II Standalone

In Type II (Standalone) The liner is designed as standalone flexible liner so that it can carry all loadings such as hydraulic, ground load and surface loads (usually traffic).

Thus the lining is designed as a flexible pipe that does not rely on bond with the sewer wall. Structural capacity results from the self strength of the lining and grout any as a stand alone liner and no long term strengt is assigned to the existing sewer body. The host sewe pipe is considered fully deteriorated and henc structural support from the surrounding soil is a mus for the liner to support the loads as a flexible pipe

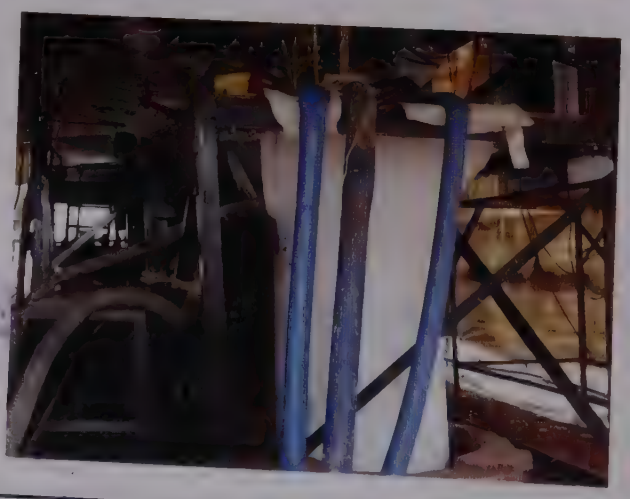
In reality, the liner (designed as Type II stand-alon liner) would act as Type II (Hydraulic) liner until the deteriorated pipe is fully disintegrated and that soi modulus of the surrounding soil is fully mobilized fo the flexible liner to achieve its fullest (designed structural capacity. Hence in Type II (Standalone) design, a check shall be carried out for the design thickness to ensure that it also meets hydraulic loading requirement for Type II (Hydraulic) design for "intact" sewer.

Structural Liner Options

Three lining systems have been identified that are capable of meeting the basic requirements to the sewer rehabilitation works in Delhi. These are described below.

Cured In Place Pipe Liner (CIPP)

The CIPP process involves inserting a resin impregnated fabric (felt or fibre) liner tube by an inversion process into the sections nominated for structural strengthening.



By heating the water filled liner, the liner is cured to become a self supporting pipe within the host pipe.

The tube is manufactured in a factory controlled quality environment. The impregnation is usually done in purpose built shed (usually for man entry size sewers) near the inversion site and requires good skill of trained workers. The impregnated tube shall then be inserted into the sewer by inversion process as quickly as possible and before any onsite setting of resin takes place. The water filled inverted liner is then heated up carefully by hot water circulation. The process shall be carefully controlled, specially the rate of raising the temperature and the cooking period of the liner. The whole installation process requires fairly good trained staff.

The CIPP process is widely used worldwide for rehabilitating non-man entry size sewers. In recent years, the process has been also used to renovate or rehabilitate structurally weak man entry sewers. DJB used this technology in 2003 to 2005 to rehabilitate sewer of diameters ranging form 1200mmm to 1900mm and the application has been very successfully done.

The liners were designed as standalone structural liners to carry all ground, traffic, and water loadings. The maximum diameter of CIPP liner successfully installed overseas is 2.75m. The CIPP process results in a seamless, joint-less "pipe-within-a-pipe" with a smooth, continuous inner surface which usually increases flow capacity. The installation requires full flow diversion.

Performance Characteristics (CIPP)

Structural Integrity

CIPP restores structural integrity of the sewer pipe. The product has been in service for about 35 years and independent test results confirm that the CIPP is structural product with 50 year life span.

Materials

The Tube is made of one or more layers of absorbent non-woven felt fabric. The resin system used is corrosion resistant polyester, vinyl ester, or epoxy system including all required catalysts, initiators or hardeners that when cured within the tube creates a composite pipe.

Enhanced Flow capacity

It can be designed to provide least cross sectional area reduction and provide a joint less pipe. Wrinkle formation during curing of larger diameter liners can some times cause hydraulic problems but this can be minimized by carefully installing the liner.

Affordability

The product cost is relatively high due to the high content of resin. But the overall rehabilitation cost taking into account of all other work elements involved in sewer rehabilitation, the cost is likely to be comparable to similar liner systems.

Installation Know how

The know how is highly specialized and through the work performed in Delhi in the past, a considerable installation know how is available in Delhi.

Track Record

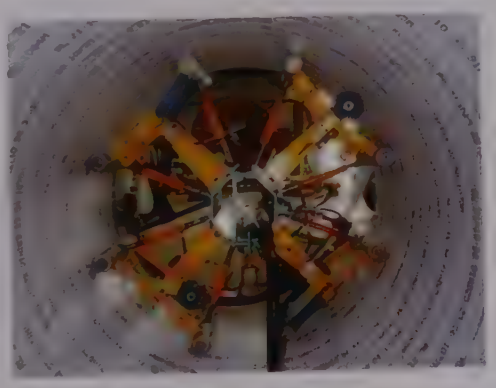
CIPP has been used in Delhi for larger diameter rehabilitation. Many overseas contractors also have technical expertise for CIPP lining

Usage sizes

- Used for all sizes of sewers
- Can be designed as standalone structural liner for man entry size sewer

Spiral Wound System

An uPVC strip can be wound into the sewer by machine or by hand and locked together on the edges



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(CLIC)

to form a continuous spiral pipe. Once installed the any annulus left between the lining and original pipe would be filled with grout.

Two possible systems are available. The Rib loc system uses a machine which traverses the length of the pipe or is placed at a manhole and winds the strip into place inside the existing pipe. The system has been successfully used on recent sewer rehabilitation project by DJB on non man entry size sewers. It can be installed through mild bends but this depends on the geometry of the bend. The uPVC strips are about 150 to 200mm wide and they are wound within the sewer to be rehabilitated. Once the spiral pipe reached the target manhole, a steel wire already wound in between the main and the assembly lock is pulled out which uncouples the assembly lock and allows the pipe to be expanded to fit into the host pipe.

The Panel Lok system is similar and requires man entry to place the lining within the host pipe. This system has been used in Australia and USA. The system may be able to make use of bind strength to the existing pipe to resist hydrostatic pressures but this requires additional work for surface preparation.

Both systems require full flow diversion to carry out the liner installation work.

Performance Characteristics (Spiral Wound)

Structural Integrity

Rib loc liner can be designed as structural liners to restores structural integrity of the sewer pipe. The product has been in service for about over 15 years and it can have a life span of 50 years

Materials

The liner material is predominantly uPVC and the ribbed strips are made in factory controlled quality environment. No wet parts are involved during installation and the installation process is fully mechanized. Cement grouting is required to fill the annulus.For larger diameter sewer rehabilitation, stainless steel stiffening ribs are added to enhance the stiffness capacity of the pipe and to meet the required structural capacity of the sewer. Recent addition include steel strip encapsulated liners known as RibSteel.

Enhanced Flow capacity

It can be also designed to provide least cross sectional area reduction. It has water tight mechanical spiral joint or fused joint along the product pipe and the tests have shown the joint to be water tight. The liner material, uPVC, offers least flow resistance

Affordability

The product cost is relatively low when used without stainless stiffener ribs and grouting. However the overall rehabilitation cost taking into account of all other work elements involved in sewer rehabilitation and the cost of stainless stiffener, the cost is likely to be comparable to other structural liner systems.

Installation Know how

The know how is highly specialized and through the work performed in Delhi in the past, installation know how is available in Delhi.

Track Record

Spiral wound liners have been used in overseas, mainly for smaller diameter rehabilitation. In the recent years spiral wound system has been also used for rehabilitation of larger diameter pipe. In recent DJB projects, the system has been used for rehabilitating non man entry size sewers.

Usages Sizes

- Predominantly used for non man entry sewers
- Can be designed for use as structural liners for man entry size sewer

GRP Liners

Structural strengthening of deteriorated sewer using GRP liner pipes have been also widely used worldwide for rehabilitation of sewer in particular for strengthening

of deteriorated man entry size sewer. The GRP, as a material is in existence for more than 50years

The lining is comprised pipes made of various combinations of fiberglass mats, glass fibres, and resins and. sometimes, silica sand.

The pipes are manufactured off site in a factory controlled quality environment. A 2-3 mm thick resin layer is incorporated to form a corrosion resistance barrier to the inner surface of the liner pipe.

Since the GRP pipes are pre-made for insertion, it is necessary for the contractor to make accurate measurements of the internal diameter of the sewer to be lined. The pipe lengths are usually connected through a rubber ring joint or are glued with epoxy resin. The joints are designed to be watertight.

Runs up to 200-300m can be installed from a manhole or a launch pit. A special trolley is normally used to transport pipe segment to its position in the sewer. The pipe installation starts from the opposite end of the pipeline so as to finish in the launch pit. Once the pipes are installed within the sewer, the annular space is filled with grout.

GRP liner have been used as Type I composite liner and Type II standalone liners in Mumbai and Delhi

Full flow diversion will be required to carry out the liner installation work.**OL MOR**

Performance Characteristics (GRP)

Structural Integrity

GRP liner can be designed as structural liners to restore structural integrity of the sewer pipe. They are good as Type I liner in which the existing structural capacity of the host pipe is made used. The product has been in service for about over 50 years and it can have a life span of 50 years or more.

Materials

The structural wall shall be made up from resin impregnated layers of E type glass fibre separated by a polymer mortar core. The fibre reinforced skins shall include resin with a quantity of fine fillers. The core element shall be comprised of filler and aggregates bound by a resin matrix. The same resin, applied to the whole structural wall element in a single application, shall be employed in both the reinforcing and core layers.All structural layers of the GRP liner shall be produced in a single-injection process whereby structural core elements and reinforcing layers are formed in a singular resin infusion step. The manufacturing of the liner is done under factory controlled environmentGrouting is applied to fill the annulus. In case of Type 1 liner, good quality control is need for the grouting work.

Enhanced Flow capacity

It can be designed to provide least cross sectional area reduction. The internal surface of the liner is smooth and offers least flow resistance surface. The circumference joint is about 1.5m to 2m interval depending on the length of GRP pipe liner lengths. The joints are water tight

Affordability

The product cost is similar to any liner made of polymeric materials. However the overall rehabilitation cost taking into account of all other work elements involved in sewer rehabilitation, the cost is likely to be comparable to similar liner systems.

Installation Know how

The know how is also specialized and through the work performed in Delhi and Mumbai a considerable know how now exist with contractors in India.

Track Record

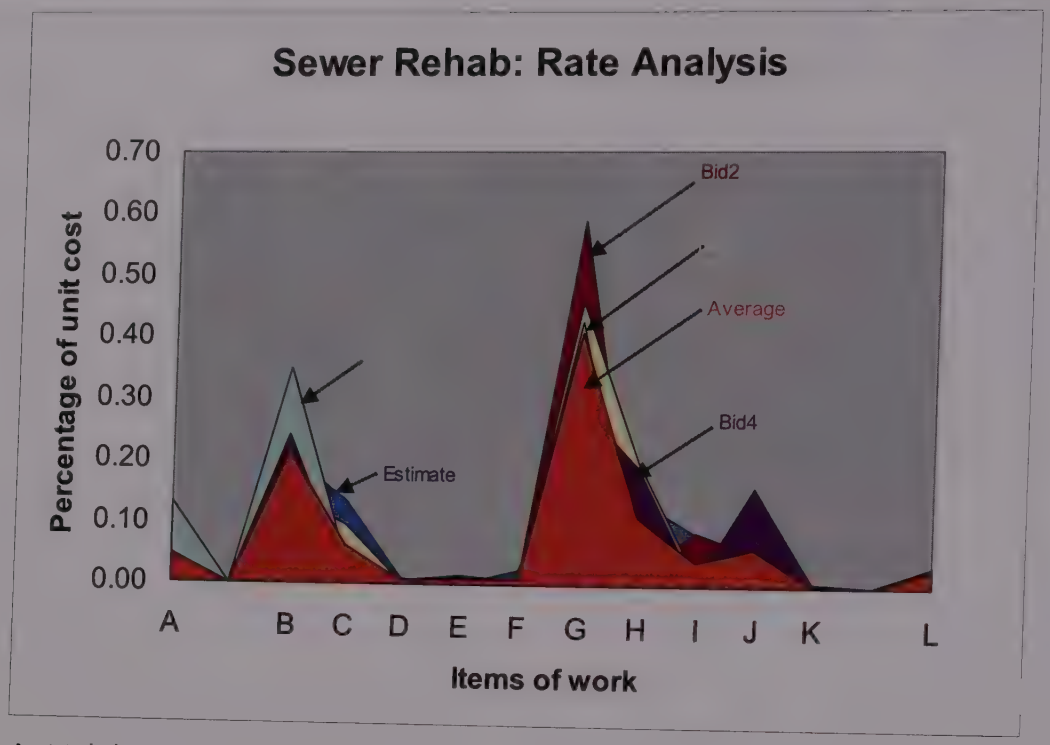
GRP liners have been used extensively in overseas, mainly for rehabilitating larger diameter sewer. In recent DJB projects, the GRP liner has been used for rehabilitating man entry size sewers. In Mumbai, GRP liners have been extensively used for rehabilitating larger diameter sewer both ovoid and circular sewers.

Usages

- Used only in man entry size sewers.

Cost of Sewer Rehabilitation

The major cost elements in sewer rehabilitation works are:-Cost of liner and its installation which accounts for 40% to 55% of the total cost. Next comes the cost of flow diversion which varies between 20% and 30% of the total cost. The following cost graph based on recent rehabilitation works illustrates the cost of various work elements in sewer rehabilitation works (3).



A: Mobilization, **B:** Flow Diversion **C:** Desilting, **D:** CCTV Survey, **E:** Repairs, **F:** Sewer Survey, **G:** Liner Manufacture, **H:** Liner Installation: **I:** Grouting, **J:** Manhole Rehabilitation, **K:** Post Rehabilitation CCTV, **L:** Reinstatement works

N.B. The findings, interpretations, and conclusions expressed in this paper are entirely those of the author and should not be attributed in any manner to any organizations or establishments referred to or implied in the paper.

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Quality of couplers in use for jacking and micro tunnelling

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The Netherlands

Introduction

D.I.S Enbi Seals Ireland Ltd is a European company with global orientation providing sealing systems for pipelines. Our headquarters are in Ireland, with facilities based in The Netherlands and in India.

Enbi was originally started in 1947 and is owned by the current management team since 1997. We have design, development and production facilities worldwide. We currently employ 140 people worldwide.

Our primary business is the development, production and sales of rubber seals and all accessories that combine rubber for usage in pipe systems. Most of our range of products are developed in co-operation with our customers. Some of these are introduced to the open market in agreement with them.

The focus for my presentation is on our range of Jacking Pipe and Micro Tunneling couplers and Inner-liners. For this range of products we had been producing rubber parts for more than 15 years. In 2004 DIS Enbi Seals Ireland acquired the design and production facilities from Flexseal UK Ltd for their full range of couplers and inner-liners.

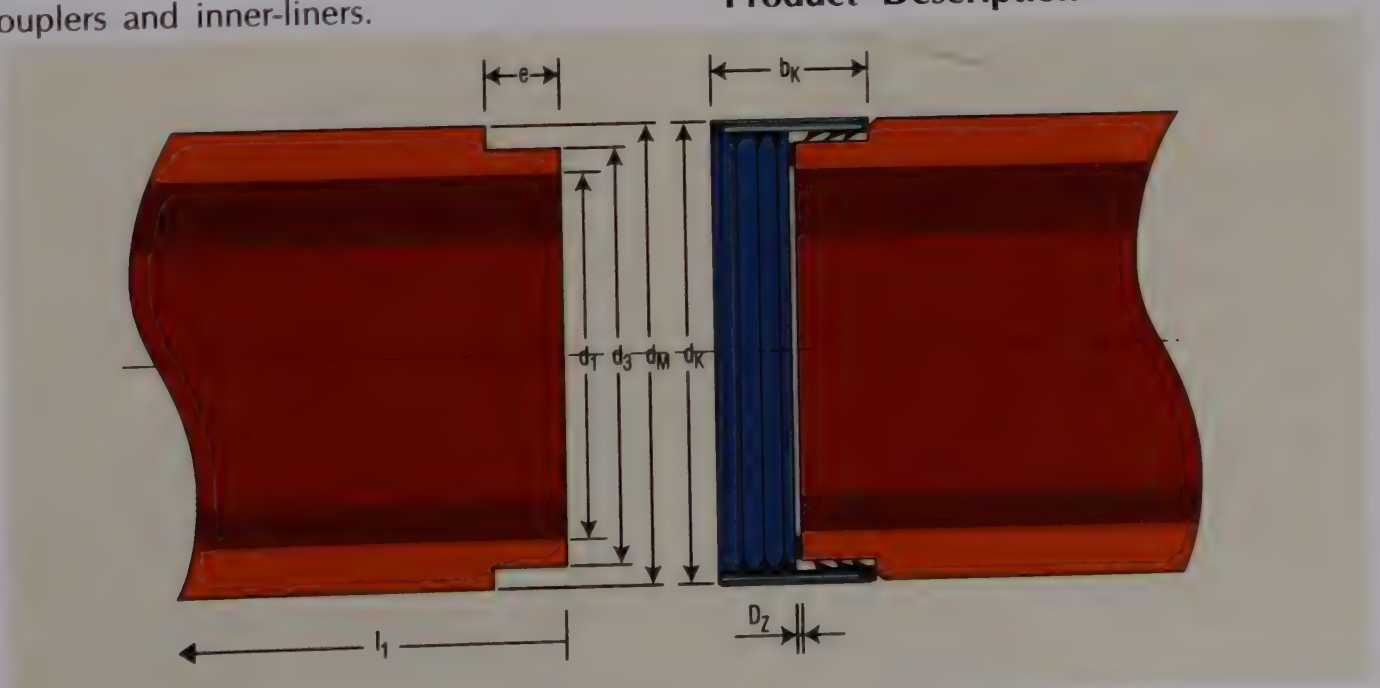
D.I.S. Enbi Seals is the first company who has all of the necessary facilities to design, develop and produce the full range of JPCs under one roof. We design and produce the rubber parts and housings and assemble these parts along with the pressure transfer ring to form a coupling which is "fit for purpose" to the optimum. Water tightness test facilities are available in our well-equipped laboratories. All basic mechanical and chemical tests required can be done in-house.

All design, production and test facilities are under the control of an Approved Quality Assurance System complying with the requirements of ISO 9001. D.I.S. Enbi Seals Ireland is a BSI Registered Firm of Assessed Capability, certificate No. FM 22579.

Third parties can certify products as required by the customer. At this moment we have product certification from controlling agencies such as BSI(UK), MPA(Germany), KIWA, KOMO, GASTEC (Netherlands), DGS (France).

The full production range can be produced at our facility in DIS Enbi Ireland and DIS MRP Chennai.

Product Description



Housing of jacking pipe coupling or inner-liner

For producing steel housings), first we cut steel strip to the specified length. This is the rolled to circular shape and TIG welded in that position. To make the housing more rigid, often the steel is given a profile by cold rolling. The materials most in use are the following grades of Stainless steel 1.4571 (AISI 320), 1.4404(AISI 316)or 1.4301(AISI 304).

Sealing element of the jacking pipe coupling and inner-liner depending on volume and size of the coupling, the rubber part can be moulded or extruded

Extruded parts will have at least one vulcanised rubber joint.

The effective sealing of the joint is obtained by both a lip and compression sealing areas of the rubber element. The choices of compression will be in such a way that water tightness over a long period is guaranteed and that the coupling can be joined to the pipe with an acceptable push-in force.

The rubber we use is mainly EPDM. The special formula has been developed by DIS enbi seals Ireland Ltd for sealing systems and has proven capability over long-term use. Other elastomere such as SBR and NBR can also be used.

Packing ring

The packing ring can be integrated in the rubber element and made of the same or different rubber as the sealing element.

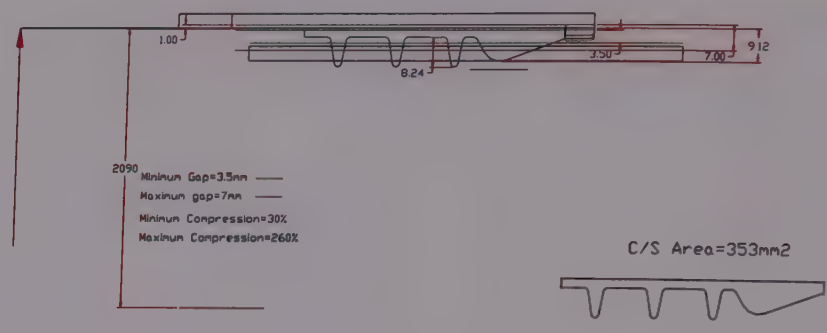
We can also provide the customer couplings with factory fitted particle board ring or we can design the rubber element as an adapter to fix the packing ring later.

Rings are made out of different materials like MDF or particle board to EN312-5. Moulded packing rings made of hard rubber can also be used and is available.

Quality aspects to be aware of

A. Sealing function

DIS Enbi manufacture Jacking Pipe Couplings (JPC) with elastomer sealing elements permanently fixed to the housing of the coupling. The rubber element is designed to incorporate dual functionality with both compression and lip sealing.



See above and example of a calculation for a seal to be used in a water pipe system for 10 Bar.

Compression sealing provides greater stability minimising lateral movements. It also compensate for irregularities and blemishes on the surface of the spigot. The sealing function is dependant on initial compression and residual stress at long term. Stress relaxation tests indicate the suitability of the material for long-term use and help predict the service life of the coupling. As an indication compression for sealing is less than 20% for a 60 IrhD element that is often preferred as an optimum for most applications. Higher compression values may result in increased push-in force to assemble the joint and may even damage the rubber element.

The lip seal adds flexibility and the sealing function is not purely dependant on the residual stress. Compression/deflection shall be to the magnitude of >50% without appreciable increase in push-in force. This flexibility in lips will accommodate lateral movements and deflection in service life due to ground movements and still ensure effective sealing.

B. Deflection & Flexibility

During its life, all pipelines are subject to lateral movements and deflections. The couplings are designed so as to guarantee sealing under these conditions. The couplings are tested to EN295-3 for shear and flex resistance.

Packing rings in Jacking Couplings are compressed progressively during jacking. The ground area of the spigot should accommodate the effect of this compression and consequent reduction in effective length so as not to damage the housing of the coupling. A picture is showed below from our test facility.

C. Quality stainless steel housing

JPC housing is built out of the austenitic range of the AISI stainless steel. Mainly AISI 304, AISI316 and AISI 320.are used. We can advise you what material to use on the basis of the inside fluid being conveyed and outside ground conditions. In the type B coupling, the inside fluid will not touch the steel housing and the rubber is little affected by the conveying fluid.

Where housing is required to be profiled, the housing we use hardened surface treated rollers. This is to prevent metal contamination on the surface of the housing

For welding, Gas Tungsten Arc process (TIG) is used. Welding rods are in use for wall thickness higher than 3mm and are in accordance with AWS A5.9-69. Mechanical properties of the weld will be at least equal to that of the base material. To guarantee similar corrosion resistance, AWS 309 range rods are used. To prevent carbide precipitation, copper bars are used .

D. Life expectation and Corrosion resistance

For the rubber used in our coupling we guarantee a proven life expectancy of more than 50 years. This is validated by stress relaxation tests according ISO 3384 on a regular basis and shows that the rubber still has enough residual stress after 50 years for sealing.

In the case of plastic housing, the design and material choice has to be such that deformation, because of creep, remains within the limits. The choice of the material also depends on the ground and fluid conditions. For stainless steel housing, the corrosion resistance of the basic material is the key to guarantee long life. Extra attention is taken during our working process to prevent damage or penetration of carbon steel on the surface of the housing. Where welding is required, care is taken to have similar corrosion protection as on the base material . All our couplings have an internal rubber element glued to the steel housing. The glue is water resistant and therefore protects the inner surface of steel.

For special service condition please note

1 In environments where pitting is a factor, it can be reduced by using material with high molybdenum content and by preventing sharp edges in housing design.

2 Where there is a threat of inter-crystalline corrosion, we recommend using low carbon stainless steel.

3 We prevent crack corrosion by designing a coupling case that has no areas where this type of corrosion can arise.

4 When working in area of extreme chemical pollution, we can advise our customers on the best selection of material.

5 In certain heavy corrosion circumstances a special surface treatment is possible that will give the outside surface, after cleaning, a new well defined protection layer caused by a passivation treatment

6 In an environment with low or no flow of seawater/ brackish water we recommend an organic surface layer on the outside of the steel housing.

7 To prevent stress corrosion we are using hot rolled SS strip. Where the strips are profiled, we recommend using SS containing molybdenum.

Conclusions

1 The life expectation of the coupler should be minimum the same as for the pipe material in use.

2 The flexibility of the coupler should take care for all ground loads and ground movements to be expected during normal circumstances

3 To prevent corrosion caused by the sewage water there should be no contact with the steel casing

4 Ground properties has to be analysed to take the right choice for the coupler material

5 Couplers have to be designed for inside and outside pressure

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100 MLD Augmentation Scheme

B R. NAGENDRA*, Dr. P N. RAVINDRA#
*Chief Engineer, #Assistant Executive Engineer, BWSSB

1.0 Introduction

Bangalore Water Supply and Sewerage Board (BWSSB) has implemented the CWSS stage IV phase I project to supply an additional quantity of 270 MLD to the city. Now the demand is increasing and BWSSB has to supply about 100 MLD of water immediately to newly added areas of Bangalore. To further augment the supply, BWSSB is looking for an economical option until CWSS Stage IV Phase II is implemented by the year 2011. As such, BWSSB wishes to pump additional water to the developing areas surrounding Bangalore to the maximum extent possible by augmenting the existing Stage IV Phase I facilities at a minimum cost so that water will be available immediately to coincide with the programmed completion of the water distribution system in the developed areas. In brief, BWSSB wishes to increase the:

- Raw water supply to 400 MLD from the present design rate of 300 MLD; this would include 25 MLD transfer to the CWSS stage I treatment plant system.
- An input of 375 MLD to Cauvery Stage IV Phase I Water Treatment Plant instead of present design input of 300 MLD; considering 2-3% wastage over 375 MLD, the treated water output through Water Treatment Plant would be about 365 MLD.
- The pumping system to pump 365 MLD instead of present design pumping discharge of 270 MLD.

2.0 Background

During the tests after implementation of the pumping system at the three pumping stations at Thorekadanahalli, Harohalli, and Tataguni, it was found that the efficiency of the pumps is more than the design value and so is the grid operating frequency, which is found to be invariably more than 49.25 Hz. Because of these factors the pumps are able to drive more water to the city. In order to reduce on time and investment it is intended to use the sixth pump and pump additional water of 100 MLD. At present, each pumping station has 5 working and 3 standby pumps. With this sixth pump working, additional water could be pumped and the standby capacity would reduce from 40 to 30%, which is acceptable as per the CPHEEO norms. Hence this project has its origin in these two changed parameters and it would be possible to supply an additional quantity of 100 MLD of water. This scheme would be required until Phase II system is commissioned. The commissioning of Phase II pipeline would take a minimum of 4 years (2011) from now.

3.0 100 MLD Augmentation Scheme

In order to implement the scheme for bringing additional 100 MLD of water a proposal was prepared, contemplating the modifications required for various components of the CWSS IV stage phase I project, which are detailed below.

1. Raw water transfer of 400 MLD
2. Water treatment plant modifications to treat additional flow of water
3. Surge protection devices for sixth pump operation
4. Improvement to Transformers at TK Halli and Harohalli to handle additional power requirement.

4.0 Raw Water Transfer

Raw Water is abstracted from the Cauvery River at Shiva Anicut about 100 km south of the city and flows via Forbes sagar and the Netkal Balancing Reservoir (NBR) to the Water Treatment Works at Thorekadanahalli (T.K. Halli). The water is conveyed through channel from Shiva Anicut to Netkal Balancing Reservoir, while from NBR to TK Halli, 9.60 km length of gravity main-1900 ID MS pipe conveys water under Stage IV Phase I Scheme, by gravity. The observed discharge through the pipeline is about 300 MLD, when the NBR level is 608.50 m (maximum level). Now, it is required to enhance the capacity of

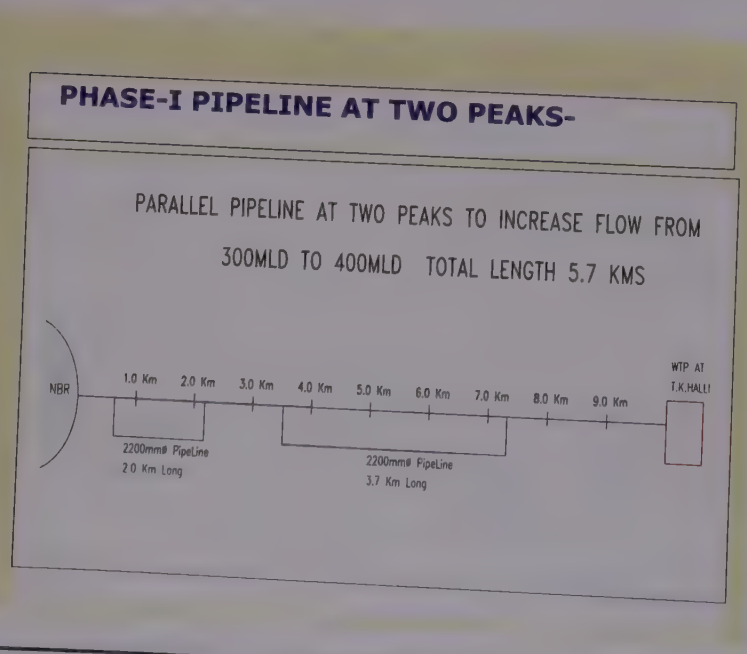
the Raw Water System to deliver a design discharge of 400 MLD considering NBR level at 608.00m. The following options were studied in detail before arriving at the final selection.

4.1 Option –1: Parallel Pipeline from NBR to T.K. Halli

A detailed study has been conducted to transmit the Raw Water Supply by gravity to an extent of about 100 MLD through a parallel line. As per the calculations, the required diameter of the parallel pipeline is 1300 mm. The proposed line has to be laid in the space reserved for Phase-II pipeline. This option involves the removal of parallel pipeline to facilitate laying of future Phase-II pipeline. More over, at the time of removal of parallel pipeline, the intended increased flows cannot be supplied through the system and hence this option is not viable.

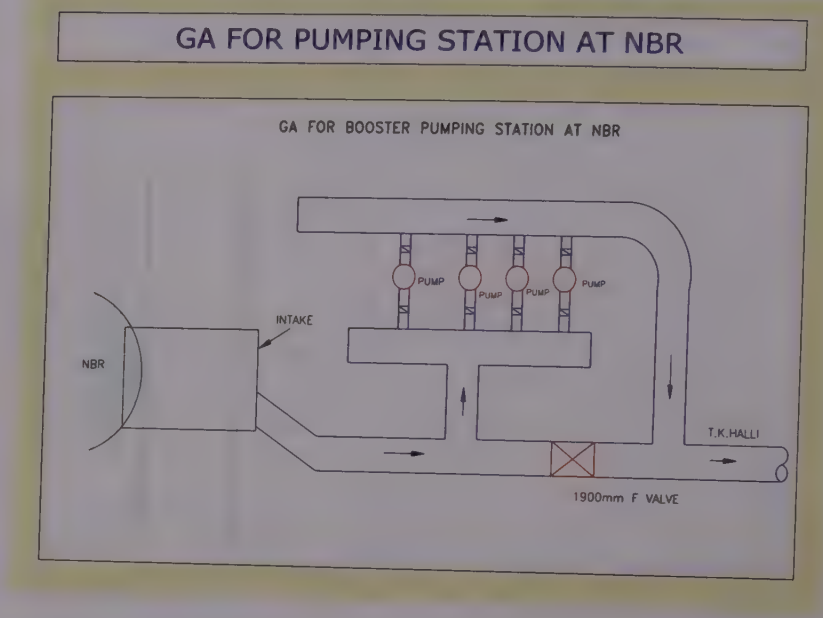
4.2 Option –2: Parallel Pipeline only at 2 Peaks

To achieve rapid progress over the Option 1, an option of laying parallel pipeline only at 2 peaks of chainage 1 km and 5.5 km were also studied. This option would not go in as a waste as the stretch of pipeline laid as part of augmentation works now would not become redundant after implementation of Phase II pipeline. This option also requires lowering of pipeline as 2 peak points to facilitate combined flow of 400 MLD to the system. Therefore, the additional expenditure to BWSSB is required only for rectification of Phase I pipeline at above peak points as required in the parallel pipeline. The BWSSB would be investing for Phase II pipeline, to address at this juncture itself which is, however, very expensive. Though the implementation of this option would require only few hours of shut down to facilitate blanking of Phase I pipeline at peak points and jointing the loop pipeline at those locations would not severely affect the water supply to the city because of cost constrains, this option is not viable.



4.3 Option –3: Booster Pumping Station at N.B.R

An option of online booster pumping station was studied to boost the required raw water transfer. The



details of pumps required for capable of pumping 400 MLD are: Pump Capacity – 400 MLD; Rated Head – 8.5 m; Motor Rating – 275kW; Number of Pumps – 2W + 2S. It is proposed to draw power supply from T.K Halli substation and a suitable overhead line for a length of about 10 kms along the service road. The implementation of this option involves only few hours of shut down in the raw water system to facilitate connection of pump suction lines and delivery manifold to the main line.

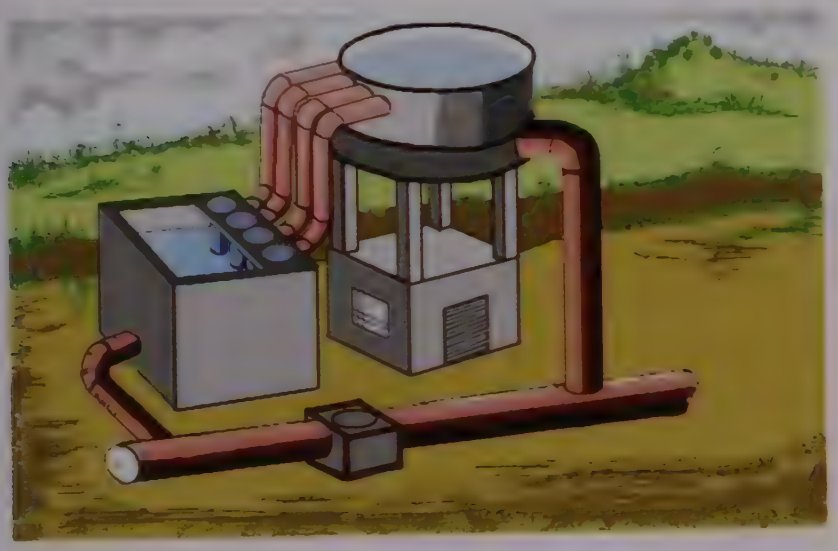
4.4 Selection of Option

Out of the two options, the Option 1 cannot be considered for implementation, as there are more demerits than the advantages of getting additional water for a small duration. Also the time and money required for implementation for laying a parallel line is enormous and may not be feasible in the context of Phase II work, which is fast approaching. The third option is possible and best suited for BWSSB to consider for implementation. This option has advantage for fast implementation and time required for implementation is only 6 months, when compared to option 1, which requires more than 18 months. The tender for the booster pumping station was floated with option for both centrifugal pumps and axial flow submersible pumps. The tender with axial flow

submersible pumps had the lowest financial implications, which is about Rupees 850 lakhs. The features of this axial flow submersible pumps option is discussed below with advantages of the scheme.

4.5 400 MLD Booster Pumping Station Scheme at NBR

The scheme, which is undertaken will house 4 nos. Submersible pump sets with close coupled submersible motors. The axial flow submersible pump sets are wet pit type and suitable for handling raw water. The pumps are closely coupled unit with axial propeller suitable for installation in a discharge column. Seating of the pump in the discharge column is accomplished by a simple downward linear motion up to the conical self-centering support ring, requiring no entry of personnel and shall not call for alignment requirements.



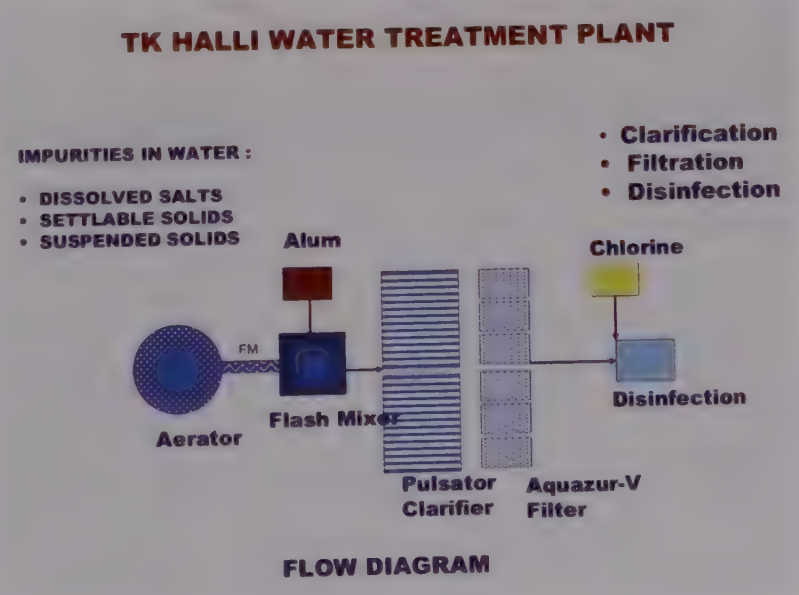
Two working pumps are designed to meet the desired discharge capacity of 400 MLD against a head of 8.5 m. The tapping will be taken from the existing gravity line and the water is diverted into a wet well, where 4 nos. submersible pumps will be installed. These pumps lift the water from wet well and discharge it to an overhead tank thereby increasing the hydraulic gradient at the intake. Each pump has its individual discharge pipeline delivering water to the overhead tank. The axial flow hydraulics is suitable for starting with open valve condition; hence, no valves are required in individual delivery lines. The pumps are suitable for reverse flow during power failure and the column pipe is designed to withstand the surge. The outlet of the overhead tank shall be connected to the existing gravity line and the water shall flow to T.K. Halli through gravity. Further when the pumps are shut off, the water in the overhead tank drains slowly thus averting the creation of negative pressure in the system. Hence additional surge protection for the pipeline is not required, other than normal air valves. The electrical control room shall be erected below the overhead tank, thus optimising the space.

The scheme is equipped with advanced instrumentation and control equipments namely;

- Ultrasonic type level measuring system will sense the level of water in the sump and overhead tank to control the working of the pumps and dry run protection as well.
- Ultrasonic flowmeter for measuring the flow from the pumping station.
- Programmable Logic Controller (PLC) and SCADA system comprising of PC, SCADA software and printer.
- The local SCADA system will be hooked up to a UHF based telemetry system. The radio communication system located at NBR and TK Halli will operate in point to point configuration. The system include UHF radio stations fully equipped with transmitters, receivers, multiplexers and data cables, radio modems, antenna and accessories.

5.0 Water Treatment Plant

The existing Stage IV Phase I - 270 MLD water treatment plant is constructed with sludge blanket type pulsator clarifiers and high rate Aquazur-V filters. Sludge treatment is provided in the form of sludge thickener and centrifuge with polyelectrolyte dosing system. Automation for operation of treatment plant also provided including water quality monitoring. A detailed study was under taken to assess:



- The potential impact on the operation of the existing works under an increase in input from 300 MLD of raw water to 375 MLD (equivalent to an increase in 27%), and an increase in output from 270 MLD to 365 MLD (equivalent to an increase of 33%).

- What remedial measures may be necessary to maintain acceptable performance?

5.1 Trial Tests

To ascertain and quantify the quality of the output by the process test at the works, the testing at site considered is described here. Pulsators have been designed to accommodate hydraulically a 50% increase in the design flow. However, the deterioration, if any, in performance of the Pulsators due to increased flows needs to be studied. Aquazur-V filters have been designed to accommodate hydraulically a 20% increase in the design flow. However, it was necessary to test whether they may be able to accommodate the increased throughput without any deterioration in quality of treated water.

5.2 Process Test Findings

Process tests were conducted to ascertain and quantify the quality of the output for the above mentioned units. During the tests, by shutting off one pulsator, increased flows were taken into the remaining three Pulsators. This has achieved a flow to an extent of about 100 MLD to each of the three Pulsators. Subsequently 3 filters were taken out of service to allow flows only through 9 filters. This has ensured 33.4 MLD flow into each of the 9 filters in service. The above arrangement was carried out to simulate increased throughput to an extent of 375 MLD expected at a later date.

As per the tests conducted at the site of the treatment plant by simulating the increased flow by shutting of some units observations have been made. The performance of the Pulsators deteriorated due to increased flows, when compared to the working of Pulsators with normal flows. However, the final filter water quality is well within the stipulated values except the residual aluminium content, which was in the range of 0.20 to 0.35 mg/L, against the permissible range of 0.03 mg/L as per the international standards. Barring the aluminium content, the treated water quality was found to be fit for potable supply. Also the filter runs got nearly halved, i.e. from 78 hours to 40 hours. Therefore, so as to maintain the quality of Pulsator output and at the same time to ensure acceptable treated water output, the existing system cannot be overloaded. To arrive at the requirement of additional units process trial tests were repeated with four pulsators and 11 filters for an output of 300 MLD to simulte 400 MLD flow. The final filter water quality is well within the stipulated values of turbidity less than 0.35 NTU. The residual aluminium content was in the range of 0.020 to 0.03 mg/L, less than the permissible range of 0.03 mg/L as per the international standards. Also the filter runs were near 70 hours to 75 hours.

5.3 Conclusions

- **Treatment System**

Without additional process units, though the filters have produced acceptable quality of treated water, but the residual aluminium content exceeded the limits due to under performance of pulsators subjected to increased flows. Hence it was considered necessary to construct additional one pulsator and two filters to ensure the same treated water quality and also the filter runs. This conclusion was based on the process trial tests carried to simulate the behaviour of the treatment system with additional units. The additional units require few modifications at Distribution chamber and certain operational requirements at inlet gate to bypass channel/individual feed chambers to ensure uniform flow to all the pulsators.

- **Pre Chlorination**

The existing system contains one duty and one standby chlorinator, each with a maximum capacity of 40 kg/hr. This was provided considering to dose the raw water with up to 3 mg/L at the design throughput of 300 MLD. Increasing the throughput from 300 MLD to 375 MLD will result in an increase in chlorine consumption at maximum usage rate to 47.5 kg/hr. Therefore the present system would not be sufficient unless an additional chlorinator is provided. However, it is to be noted that since from commissioning of the treatment system (July 2002), the prechlorination has been maintained at or about 2.5 mg/L, with no problems of algae growth. Considering the same dosage, the existing one working and one stand by of 40 kg/hr chlorinators would be sufficient for increased flows.

- **Alum Dosing**

Increase in throughput from 300 MLD to 375 MLD will result in alum usage to 8 tonnes per day at a dose of 22 mg/L of 5% solution. It is possible to accommodate this increase in alum usage by increasing the flow through the constant head-dosing box provided with V-notch and/or by increasing the concentration of the alum stock solution.

- **Flash Mixers**

A single flash mixer is not capable of providing adequate mixing, due to low generation of velocity gradients and low detention time, because of increase in throughput from 300 MLD to 375 MLD. Hence the two flash mixers could be used in parallel to accommodate the increased throughput. Operating with two duty flash mixers and no standby is an acceptable mode of operation.

- **Chlorine Disinfection**

The existing system contains one duty and one standby chlorinator, each with a maximum capacity of 40 kg/hr. This was provided considering to dose the treated water to an extent of 3 mg/L at the design throughput of 270 MLD. Increasing the throughput from 270 MLD to 365 MLD will result in an increase in chlorine consumption at maximum usage rate to 45 kg/hr. Therefore the present system would not be sufficient unless an additional chlorinator is provided. However, to maintain the residual chlorine in the treated water to an extent of about 1 mg/L at the clear water reservoir, dosing chlorine at the rate of maximum 2.5mg/L of treated water is sufficient as observed during four years of working on the system. Hence 2.5mg/L dosage for 365 MLD throughput, the existing one working and one standby – 40kg/hr chlorinators would be sufficient.

- **Residual Management**

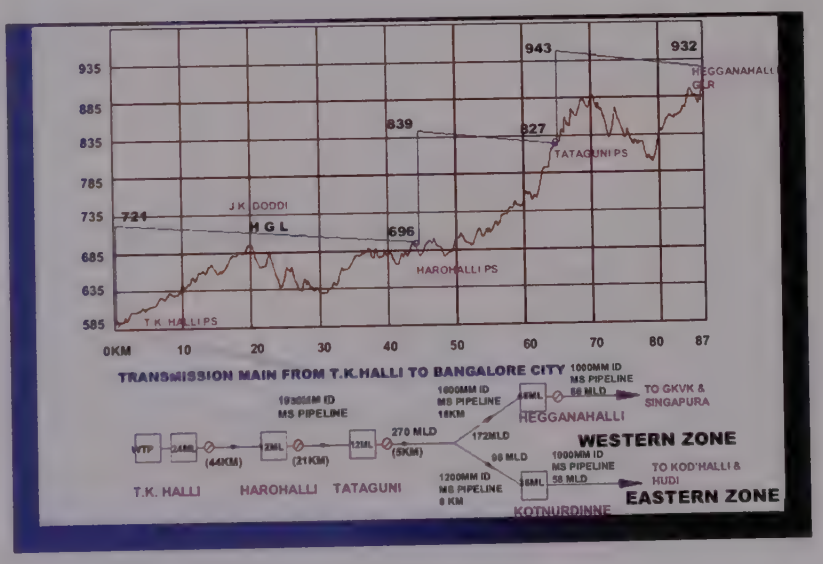
The existing wastewater and sludge treatment system should be able to accommodate the increased throughput, because the residual management systems are designed for 100 NTU of turbidity against the normal turbidity of about 4 to 6 NTU in the raw water. Only 25 days in a year turbidity exceeds 25 NTU that to in the form of flash only and not on continuous trend. Hence the capacities of thickener feed pumps, thickeners, thickened sludge pumps, centrifuge feed pumps and the centrifuges are quite sufficient and do not need any modifications.

- **Implementation**

With the above criterion in mind the tenders were invited however with the option for conventional treatment plants also to have the competitive offers. The tender with retrofitting the existing system was lowest when compared to the conventional treatment system. The work has started for construction of one distribution chamber, one pulsator, and two filters, with all necessary modifications to the civil, mechanical, electrical and instrumentation works.

6.0 Clear Water Transmission Main

The system is designed for pumping 270 MLD treated water with 5-pump operation. However, provision for sixth pump operation is provided for the catch up mode. The pumping system is designed by considering the grid operating frequency at 48.5 Hz. Since from the time of commissioning during July 2002, it has been observed that most of the time the grid operating frequency is above 49.25 Hz and which in turn has increased the discharge by about 15%. To pump 365 MLD through the system, which has been designed to pump 270 MLD, the sixth pump operation is mandatory. As such it was necessary to undertake the detailed study of the surge analysis of the transmission system including that of the transformer rating capacity.



6.1 Pumping Station at T K Halli

The detailed study revealed that no further improvements are required for surge protection system to run 6 pumps continuously and the existing surge protection system will ensure that the surge pressures are well with in the designed pressures of the system. However, the improvements are required to augment the transformer capacity for the continuous operation of sixth pump and the required rating of transformer can be achieved by adopting additional cooling system from 8 MVA to 9 MVA.

6.2 Pumping Station at Harohalli

The study revealed that improvements are required for surge protection system to run 6 pumps continuously for the intended discharge. The options studied for improvements for surge protection system are:

A. By considering on line Non-Return valve with one additional surge vessel of 65 cum of volume is required in addition to venting arrangements for two air valves located at Chainage 60 km and Chainage 62 Km.

B. By neglecting on line Non-Return Valve with two additional surge vessels of 65 cum of volume is required in addition to venting arrangements for two air valves at Chainage 60 km and Chainage 62 Km.

Going by the experience of the BWSSB and the reliability, the second option of providing two additional surge vessels was considered. Also the power supply arrangements require modifications to run 6 pumps continuous operation. Hence the improvements are required to augment the transformer capacity for the continuous operation of sixth pump and the required rating of transformer can be achieved by adopting additional cooling system from 8 MVA to 9 MVA.

6.3 Pumping Station at Tataguni

The study revealed that no further improvements are required for surge protection system to run 6 pumps continuously and the existing system will ensure that the surge pressures are well with in the designed pressures of the system. However, venting system to be improved at two peak points in the pumping main towards Kotnurdinne GLR at Chainage 3.5Km and 4.5Km. The power consumption for running 6 pumps is well with in the existing transformer capacity unlike the other two stations and hence no further modifications are proposed.

6.4 Upgradation of 4 nos. existing transformers at TK Halli and Harohalli

The existing 2 nos. 8 MVA 66kV/ 6.6kV ONAN transformers supplied each at TK Halli and Harohalli pumping station sites catered to the existing pumping philosophy. However, with additional 100 MLD being pumped under the new scheme, it is required to start an additional HV motor at the respective sites, which necessitates upgradation of the existing transformers. Thus, the 2 main transformers at the above 2 sites need to be upgraded as a part of this scheme. The upgradation of each of the transformers would be carried out by provision of a transformer cooling system. Minimum 2 fans per transformer will be provided as 'standby fans'. A provision for 'Auto' and 'Manual' operation will be provided in the control panel.

7.0 Cost of Scheme

The scheme has been now under implementation stage and 50% of the work has been completed. The cost of this 100 MLD augmentation scheme is given in the following Table 1 for ready reference. The scheme is expected to be commissioned by middle of June 2007. The investment on this project will come back within one year after commissioning of the scheme. As such this scheme is financially viable and the BWSSB's engineers envisaged this scheme.

Table 1: Cost for 100 MLD augmentation scheme

S.No	Component	Cost in Rupees
1.	Raw Water Transfer with Booster Pumping Station at NBR	730,00,000
2.	Water Treatment Plant	766,00,000
3.	Additional Surge Protection at Harohalli Pumping Station	100,00,000
4.	Modifications to existing 8 MVA Transformers, Upgrading 9 MVA at TK Halli, and Harohalli	20,00,000
	TOTAL	16,16,00,000

Wastewater Recycle and Reuse in India – Lessons Learnt

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Introduction

India is now facing serious environmental issues as a result of rapid economic growth, urbanization, and population growth. Environmental concerns range from pollution that is largely urban and industrial to resource management of water, land, forests, and energy. India possesses 5% of the World's fresh water but is home to 16% of global population; water use efficiency for irrigation is approximately 65% and power use efficiency for extracting groundwater is only 28%. Competition for water between urban and agricultural sectors has taken new dimensions and battles are being waged for water. Incidences involving destruction of earthen dams for release of water into downstream rivers and irrigation canals happened in states like Maharashtra and Karnataka over the last few years; the situation especially aggravates during the summer months.

Growing water scarcity and water pollution is one of the severe and well-recognized environmental problems in the country, and many donor agencies are focusing their efforts in India in the water and sanitation sector. Water has been in short supply in many cities for a number of years and to meet the growing demand has been a running target for many city administrations.

Closing the gap between demand and supply is a tough challenge for any city management, and a holistic approach towards overall water management is essential for a sustained solution. Given the current growth predictions and demands, these deficits are expected to grow unless new water resources are developed in conjunction with demand management.

Mitigation of Water Deficit

To meet the growing demand, and to reduce the water deficits, cities can choose three major paths.

1. To increase fresh water supply,
2. To reduce demand, and
3. To develop alternative resources.

Increasing the fresh water supply essentially means developing far away resources, which is expensive. Such projects typically cost more than Rs 2.5 crore per MLD, and the cost of delivered water ranges between Rs 12 – 20 per kiloliter. Prevailing tariffs in many cities are in the range of Rs. 4 – 8 per kiloliter, and they do not support such expensive projects. Demand reduction essentially means curtailing growth or compromising public health. Growth is not under the control of any municipality and increasing risks to human health runs contrary to any municipality's charter. Water boards and municipalities can reduce the overall demand of the city by reducing the distribution losses, but this again needs capital investment and strong implementation of construction codes to ensure quality.

Due to problems related to supply augmentation and demand management, Cities and States now need to consider wastewater recycle and reuse for non-potable applications because it is a captive resource and does not have trans-boundary issues. With appropriate technologies, domestic wastewater can be treated to any extent, and safe water for non-potable use can definitely be produced. It is believed that wastewater recycle and reuse can and will play an important role in a city's water and sanitation policy because reuse of treated wastewater offers unique opportunity to provide a partial solution to problems related to water as well as sanitation.

The authors have actively participated in several studies and projects concerning recycle and reuse of wastewater in Indian cities, and their experiences are presented in this paper.

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Wastewater Recycle and Reuse – Worldwide Practices

Wastewater recycle and reuse is also known as wastewater reclamation, and is a long established practice in most of the world. Whether intentional or inadvertent, the reuse of wastewater for its nutrients and as a source of non-potable water (primarily irrigation) has a very long history. Wastewaters released to surface water bodies is often withdrawn downstream and used again for both potable and non-potable purposes. The treatment provided to wastewater prior to release depends on the prevailing regulations and capacity of the local bodies for their compliance.

Some countries that are aggressively practicing wastewater reclamation are listed below

1. Tunisia: Pioneer in integrating water reuse in national water supply; has 62 wastewater recycling plants; major end uses are agriculture, landscaping, golf courses.

2. Jordan: recently adopted zero discharge to ecologically sensitive gulf of Aqaba; mostly employs secondary treatment for general reuse and tertiary treatment for urban reuse

3. Australia: started wastewater reuse recently but aggressively; all seven states now practice reuse; major end-users are farmers and industry

4. Singapore: most aggressive reuse of wastewater; reuse for semiconductor industry and also for blending with surface reservoirs for general supply including potable use; 7% of total water supply sourced from recycled water

5. United States: California and Florida have well developed reuse guidelines and statutory regulations in place; variety of applications ranging from indirect potable to groundwater recharge

6. Japan: Wide range of applications; well-established reuse practices including decentralized reuse within buildings for toilet flushing

Wastewater Recycle and Reuse – India Experience

Wastewater recycle and reuse has grown in the past decade, especially in the industrial sector, but is still at the infancy stage in the municipal sector. Water boards and municipalities of large cities such as Delhi, Chennai, Hyderabad, and medium sized cities such as Nagpur and Visakhapatnam have conducted feasibility studies for reuse of wastewater. Information on the wastewater reuse programs and their status for these cities, key drivers that made the programs succeed or fail are presented below.

Visakhapatnam

With a vision to provide better services to its citizens, Visakhapatnam Municipal Corporation (VMC) had embarked on a number of new developments. As a result of the new sewerage master plan VMC will have to upgrade its existing sewage plants along with building two new sewage plants to treat the incoming wastewater generated within the city limits. Since the City has always been in short supply of potable water, the VMC engineering staff was interested in looking at new as well as up-gradation of old plants using the advanced wastewater treatment technologies to conserve and reuse the treated effluent from these plants for non-potable application. By this process the city expected to save some amount of potable water that is being used by a number of consumers for non-potable applications.

As part of the wastewater recycling feasibility study, the project team conducted a demand assessment to understand how much of the treated wastewater could be used by VMC's bulk consumers for their non-potable application. At present all the bulk consumers use potable water for a number of non-potable applications including but not limited to cooling water, dust suppression, gardening, fire fighting, cleaning of large ships and container vessels and rail cars. The demand assessment from only a handful of consumers indicated that there is an adequate demand of 20 MLD of treated effluent for non-potable application. It was anticipated that by reusing 20 MLD high quality treated effluent, VMC will be in a position to spare additional 20 MLD of potable water that could be supplied to its retail consumers and public at large.

Based on the budgetary capital cost of 13 crores and O&M cost estimate of 1.7 crores it was anticipated that the cost of recycled water could be in the range of 12 to 16Rs/KL against the current industrial fresh water tariff between 20 to 25 Rs per kiloliter. As the project moved with industries getting interested in reusing the wastewater, the city staff got restless with the thought of loosing revenue due to reduced fresh

water demands from these industries. This thought essentially killed the project before even getting started. In addition the project got entangled between institutional and inter-agency issues and may be a water authority that has a broader jurisdiction needs to be set-up to facilitate solutions to such complex issues.

Delhi

Delhi Jal Board (DJB) operates their largest sewage treatment at Okhla of about 650mld capacity. This treatment plant employs secondary treatment, and currently supplies 50mld of secondary-treated sewage for landscaping through a 12km long pipeline. Delhi Jal Board is interested in further reuse of wastewater from Okhla, and commissioned a feasibility study for the same in year 2005. Demand assessment survey was the most important task of the study. During the survey, interviews were conducted with 750 MW Badarpur Thermal Power Station (BTPS) located at a distance of 7km from the STP, fifty-three potential consumers located close to the existing 12km long reuse pipeline, and 113 industrial units (5% of total registered units) in the nearby Okhla Industrial Area. BTPS has a potential to use 150 MLD of recycled water by early 2008, but operation and maintenance of a tertiary treatment plant and the supply pipeline will put an additional burden of Rs 7 crore/annum on BTPS for water, which will have to be passed on to the consumers through tariff increase. Therefore, BTPS is not interested in using recycled water at this time, but BTPS officials feel that wastewater reuse will be inevitable in a few years time.

Fifty-three consumers and industrial consumers in Okhla Industrial Area indicated a gross demand of about 33mld that was reduced to a conservative estimate of 10mld through sensitivity analysis, and two supply options were developed to service the demand. Non-availability of land in the industrial area was the key factor in choosing the viable supply option that proposes construction of a 10mld tertiary treatment plant in Okhla STP and supply of recycled water through dedicated distribution network. Estimated cost of recycled water to consumers is about Rs 12/kL, whereas the consumers are willing to pay Rs 10/kL to Rs 25/kL. Willingness-to-pay is the key factor that made the project feasible, and design and bid document development is expected to start soon.

Hyderabad

Hyderabad has actively pursued development of recycled water as an alternative source, and several studies on the subject have been conducted by various donor agencies. In year 2004, Hyderabad Wastewater Recycling Project was commissioned by HMWSSB to prepare a master plan for water reuse in Hyderabad. The master plan was developed with 592mld of treated sewage from proposed five sewage treatment plants as source of recycled water. Demand assessment survey in year 2004 indicated an industrial reuse potential of about 20mld, but consumers were either not willing to pay for the recycled water or were willing to buy the recycled water only during summer season. Exchange of treated sewage for fresh water was also evaluated for a proposed quantity of 300mld. The exchange option was accepted by the State of Andhra Pradesh for implementation as it resulted into landed cost of Rs 11/kL for treated water, thereby making it cheaper than Krishna Water. The exchange option has not yet been implemented because the farmers, whose fresh water was to be allocated to Hyderabad in exchange of treated sewage, are not willing to part away with their rights for the fresh water.

In year 2005, Japan Bank for International Cooperation (JBIC) funded a project formation study for the Hussain Sagar Lake and Catchment Area Improvement Project of Hyderabad Urban Development Authority (HUDA). Demand assessment study was conducted for 105 potential consumers and demand of 28mld was derived. Due to consecutive draught years in Hyderabad and steep hike in tariff for commercial consumers, acceptance of recycled water increased among the consumers. Consumers who were not willing to buy recycled water in 2004 were willing to buy the recycled water in 2005 through out the year at a rate of Rs 20/kL. Sale of recycled water was one of the revenue streams that supported financial viability of the project. The project is now under implementation by HUDA and expected completion year is 2010.

Nagpur

Nagpur is located in the State of Maharashtra, and has a population of about 2.4 million. At a distance of about 9km from Nagpur to the North are two power plants of MahaGenco with installed power generation capacity of 1940MW. The power plants consume about 150mld of fresh water and will need additional

100mld of water for the proposed capacity addition of 1500MW. Current source of fresh water for the power plant is Pench Reservoir that also supplies water to Nagpur City. Estimated water demand of Nagpur City is about 480mld and the current deficit is about 50mld. State of Maharashtra has initiated a multi-modal cargo hub project at Nagpur, and this project also requires about 110mld of water. Thus, there are large emerging demands on water in the Nagpur region, and the region will experience severe water stress because Pench Rerservoir is the only water source for the region.

Anticipating the emerging water stress in the Nagpur region, USAID funded a feasibility study on water reuse in Nagpur in year 2005. Initiation of the feasibility study in Nagpur happened at most appropriate time because MahaGenco, the power generation company, was in search of suitable water linkage for its proposed power plants of 1500MW capacity. The power plants are on the state's priority list because the industrial state of Maharashtra is facing an acute power shortage of about 5000MW that is almost 33% of the total power requirement. Officials from MahaGenco appreciated the idea of water reuse for two reasons: 1) water reuse project could be completed in two years against 5 – 7 years required for Kochi or Rahari dams, and 2) estimated cost of water reuse project was Rs 120 crores against Rs 500 crores estimated for Rahari project. Therefore, water reuse project was very attractive to MahaGenco; however, the officials were skeptical about water quality and reuse at a power plant. To answer all the technical questions and pacify the anxiety about water reuse, key officials from MahaGenco were taken to Delhi to see the reuse of 20mld of tertiary treated sewage at Pragati Power Corporation's 350MW power plant. The visit was the turning point in the reuse project, because the visit convinced MahaGenco about suitability of water reuse at power plant.

RFP document is under preparation for construction of water reuse infrastructure consisting of tertiary treatment plant and transmission pipeline. Project is expected to start in 2007, with target completion in year 2009. State of Maharashtra also issued first of its kind water reuse policy document to provide policy support to the project.

Conclusions

Water reuse is gaining acceptance among the municipal sector in India, and result-oriented efforts with positive approach are required to develop water reuse projects. Market analysis (demand assessment) is absolutely essential and shall be an integral part of any feasibility study. Water reuse has high chance of success in areas that are draught prone and have high water tariff, because these constraints generate significant willingness to pay among the consumers. Reuse by industrial consumers is attractive because tariff for industrial water supply is higher than the typical cost of recycled water, thereby providing a platform for win-win situation on financial front. Right circumstances, proper communication and presentation of benefits, and a strong supporter among high ranking officials facilitate project formation and consent among stakeholders.

A water reuse project, though financially feasible, can fail if it involves transfer of water rights, as people are adverse to 'giving up' rights in lieu of financial gains. Further, a municipal body may not be willing to implement the project if it adversely affects their revenue as demonstrated by the Vishakhapattanam experience.

Water Supply Flow Measurement – Presentation Overview

Endress+Hauser

- Requirements for measurement
- General methods applicable
- Fluid flow considerations
- Installation effect factors
- Errors expected
- Recommendations for supply management

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Water supply meters
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Slide 1

Measurements in the Water Supply Cycle

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Water Supply Flow Measurement – Presentation Overview

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General Fluid Flow Methods in Water Supply

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- DP type meters – Venturi tubes, Dall tubes etc.
- Mechanical meters
- Electromagnetic meters
- Ultrasonic meters
- Insertion probes
- Open channel methods – weirs and flumes

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Flow Metering - Typical Water Industry Usage

Water Demand Monitors;	***Magnetic meters, Venturi meters, some ultrasonic types:***
Large pipes- water supply:	***Venturi tubes, Dall Tubes, magnetic meters, insertion devices, and some ultrasonic meters***
Large raw water pipes /sewage:	***Venturi tubes, magnetic meters, some ultrasonic types***
Balance meters (150-400mm)	***Mechanical meters, magnetic meters, some ultrasonic types***
Statutory applications:	***Mechanical meters, magnetic meters***
Small bore supply 6-15mm:	***Mechanical meters, some displacement types***
Wide range metering:	***Compound mechanical, magnetic meters***
Low purchase price:	***Mechanical meters (for domestic supply)***
Industrial consumer usage:	***Venturi/DP types, mechanical meters, magnetic meters***
Open channel sewers:	***Flumes, some magnetic types, and some ultrasonic types***

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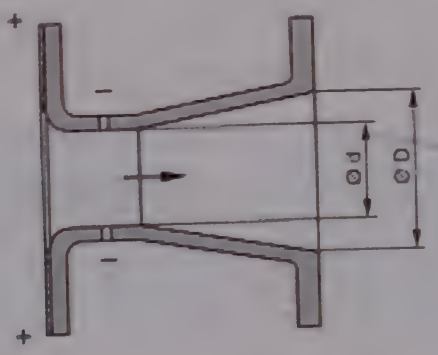
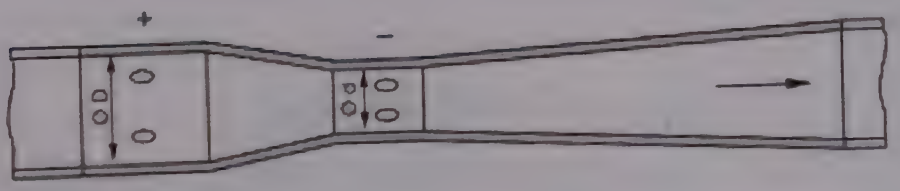
Venturi Meters: Short and Classical





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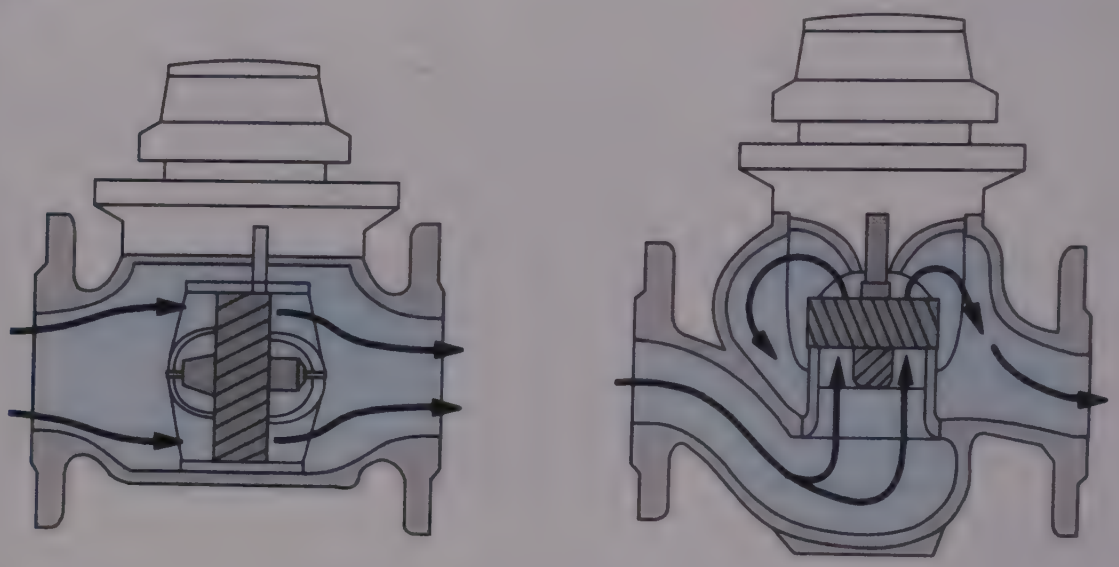
Mechanical Water Meters



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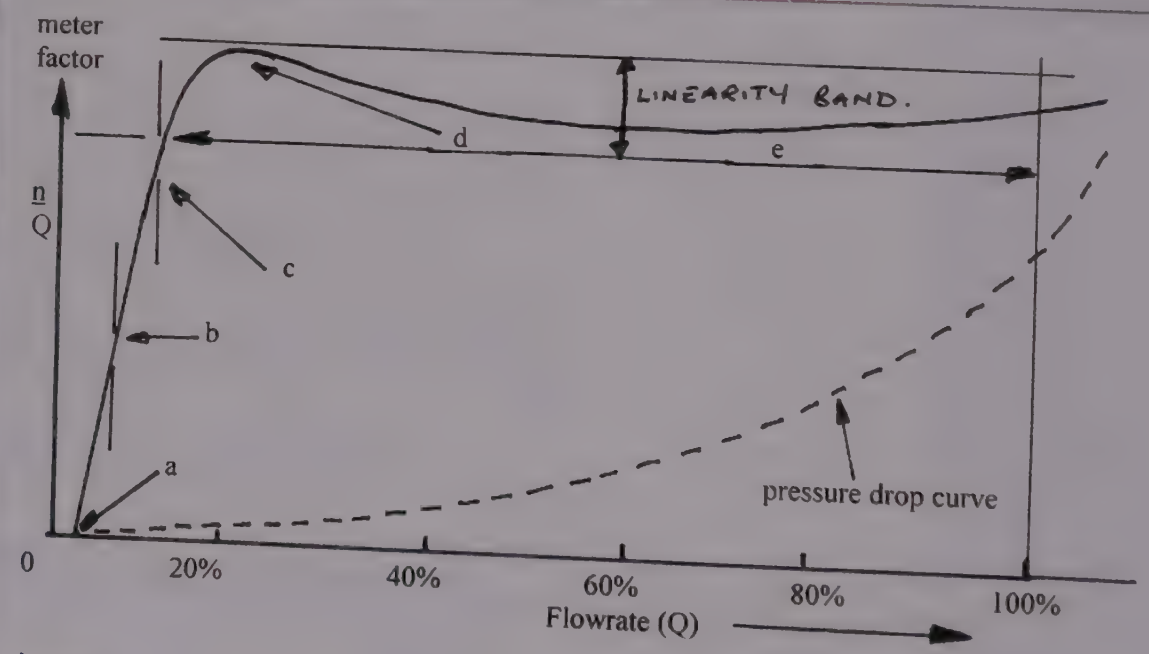
Mechanical Meter Characteristics



Legend

a = starting flowrate b = minimum repeatable flowrate c = minimum linear flowrate
d = position of maximum meter factor ('hump') e = linear operating range

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Magmeters in Water Supply

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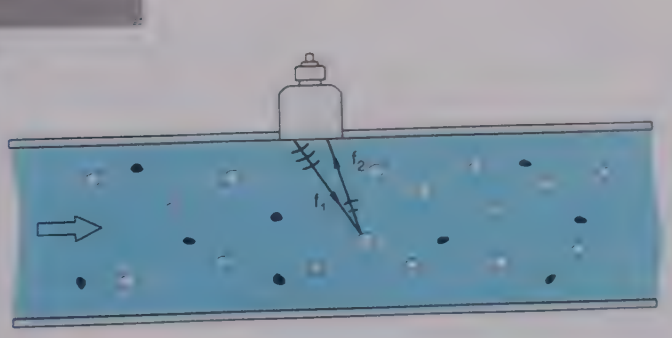
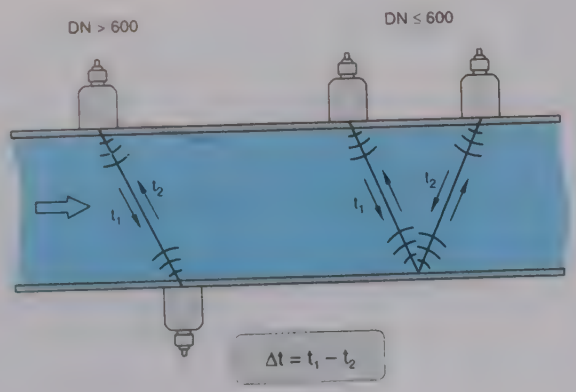
Ultrasonic meters



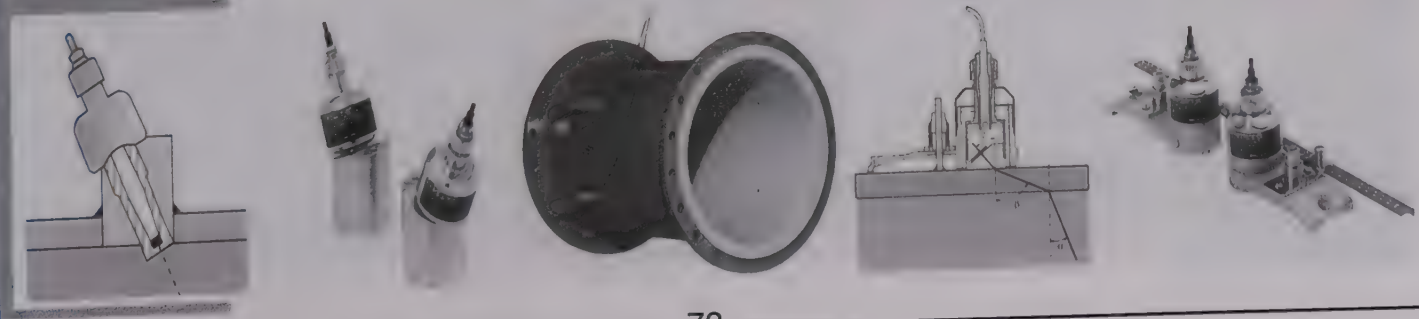
$\Delta f = f_1 - f_2$



$\Delta t = t_1 - t_2$

Doppler type for dirty fluids

Transit time for clean fluids



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Larger Lines Are More Difficult to Balance

Brazil profile studies in 1800mm lines: Multiple planes are used to map the velocity profile.

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Customer Field Studies: Brazil June 2005

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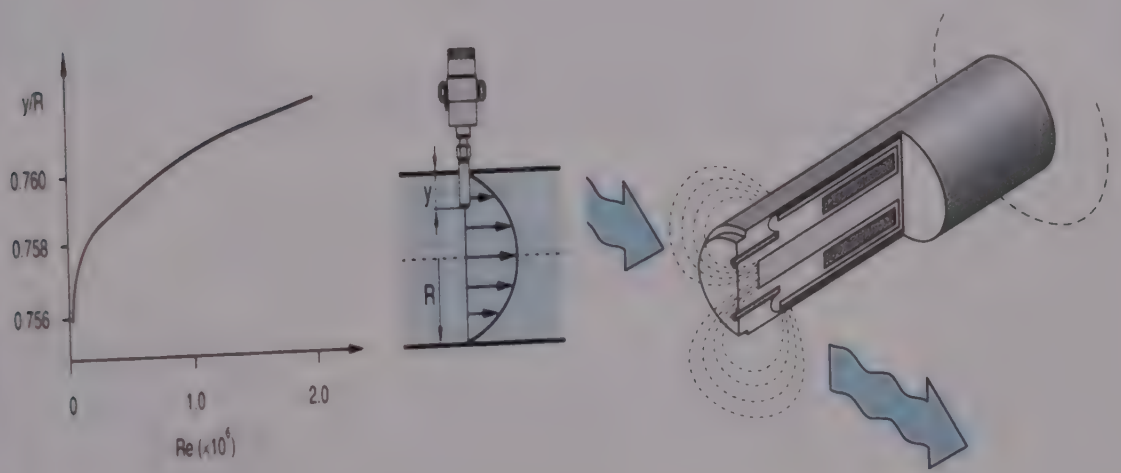
Insertion MagProbe method - schematic



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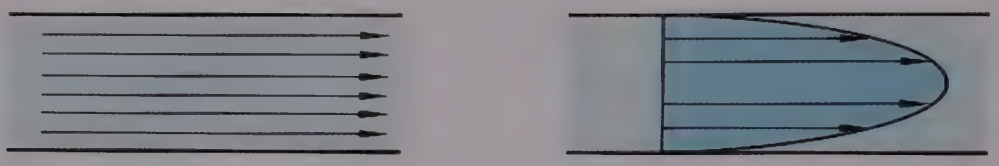
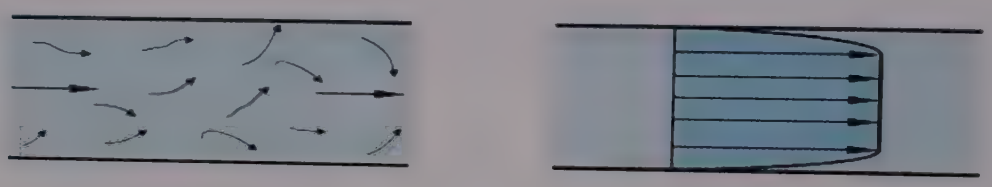
Velocity Profiles in Closed Pipe Flow

Laminar Flow - Reynolds Numbers below 2000



a b

Turbulent flow - Reynolds numbers above 5000



a b

a = fluid streamlines: b = resulting profile

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E+H Fluid Flow Knowledge

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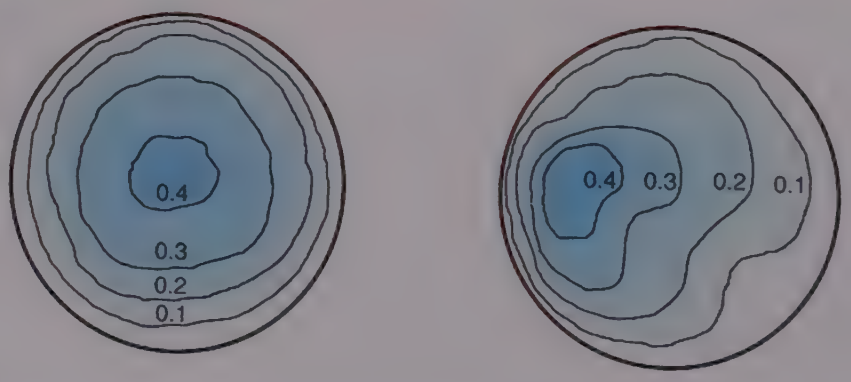
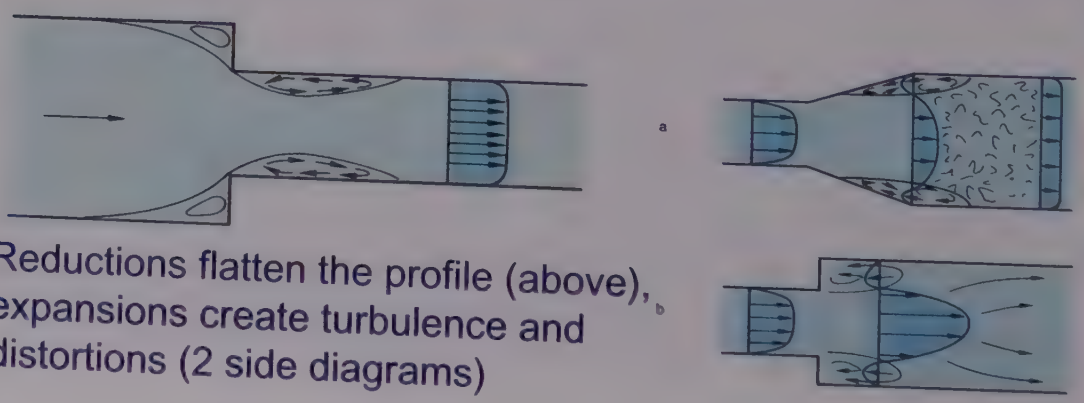


Symmetrical (ideal)and asymmetric (common) flow profiles



Reductions flatten the profile (above), expansions create turbulence and distortions (2 side diagrams)

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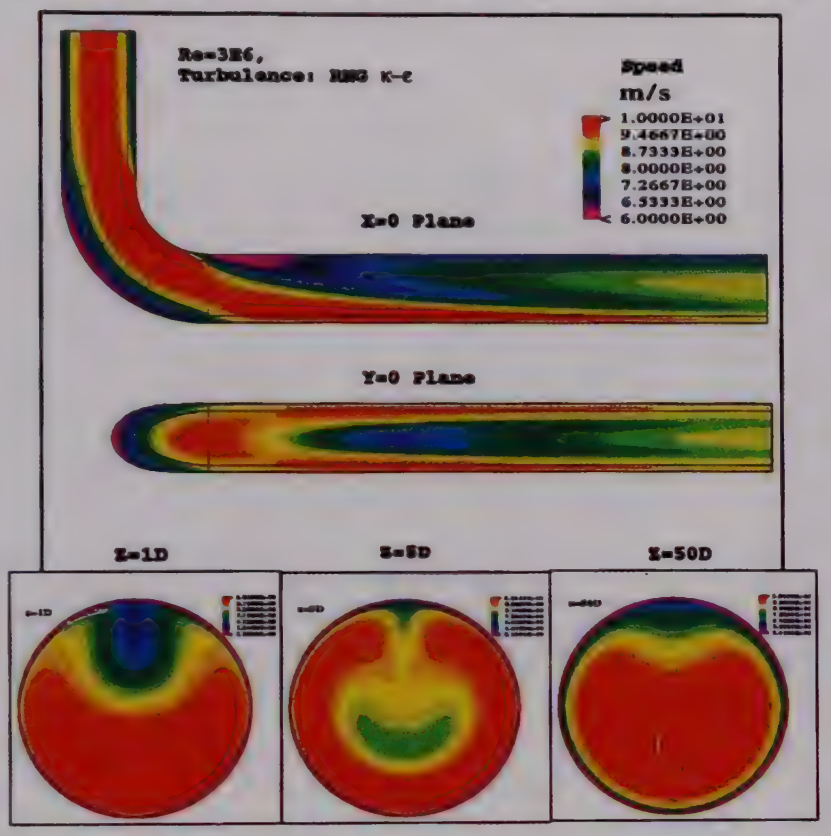
Computational Flow Modeling in Bends

CFD Results for Flow Through an Elbow



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Flow Pattern Observed 6D After Bend

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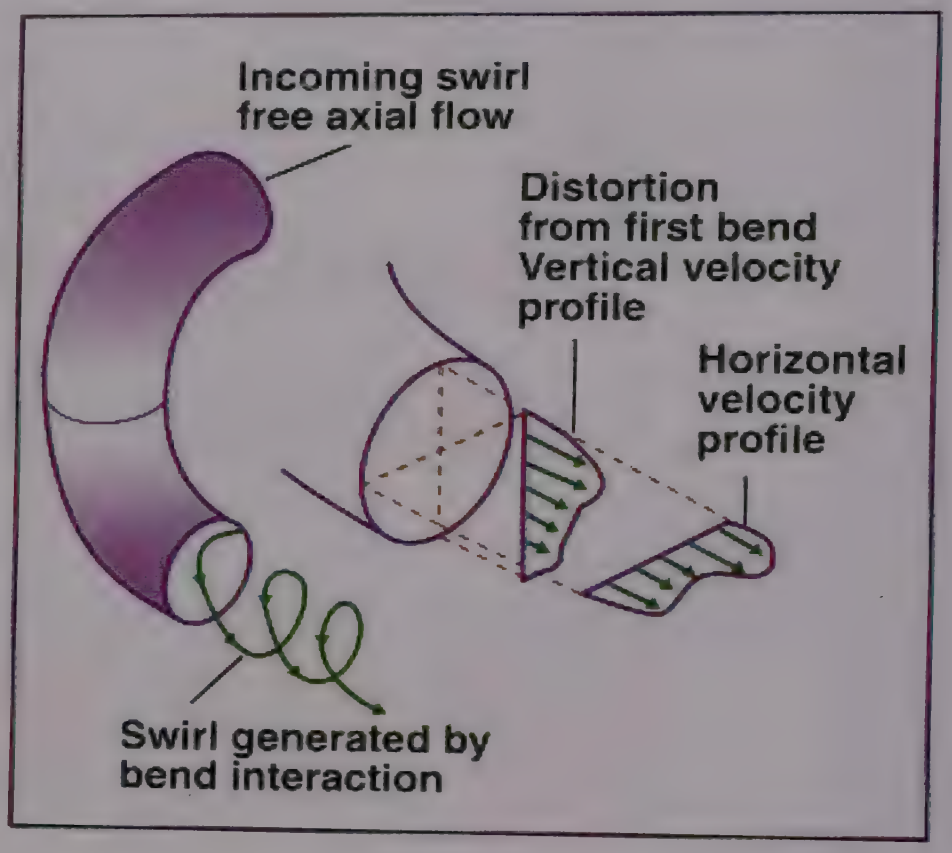
Flow Effects in Bend Combinations



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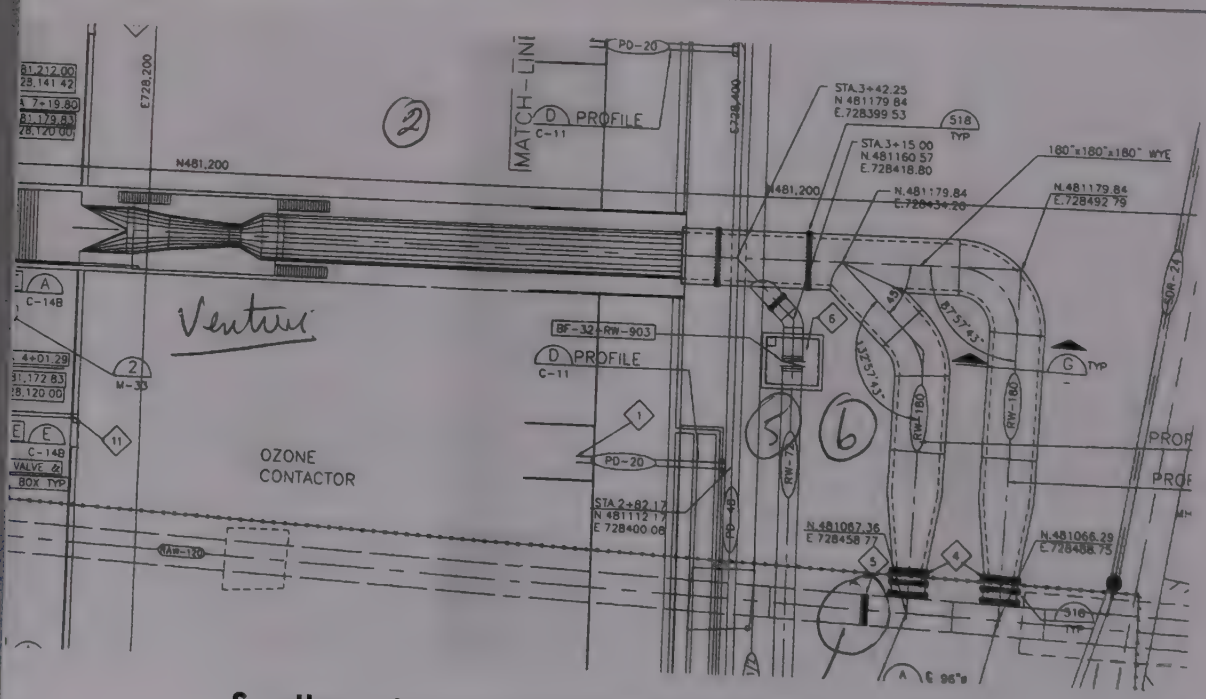
Installation Conforming to Standards



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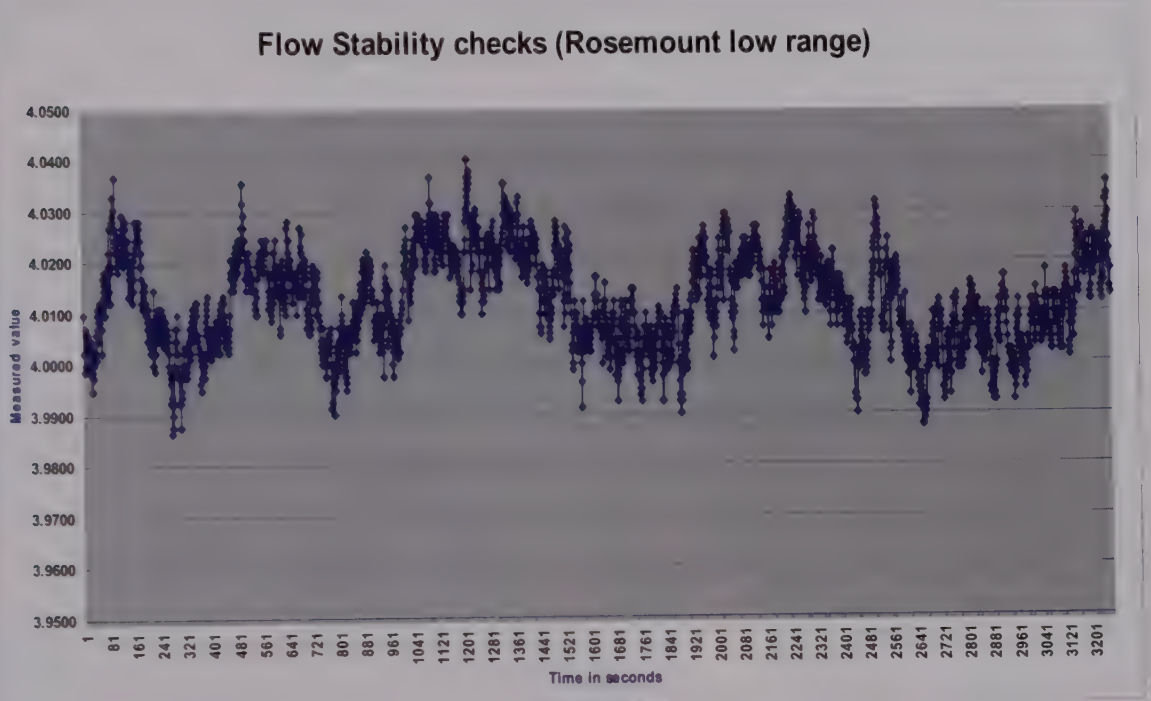
Flow Stability in Swirling Flow



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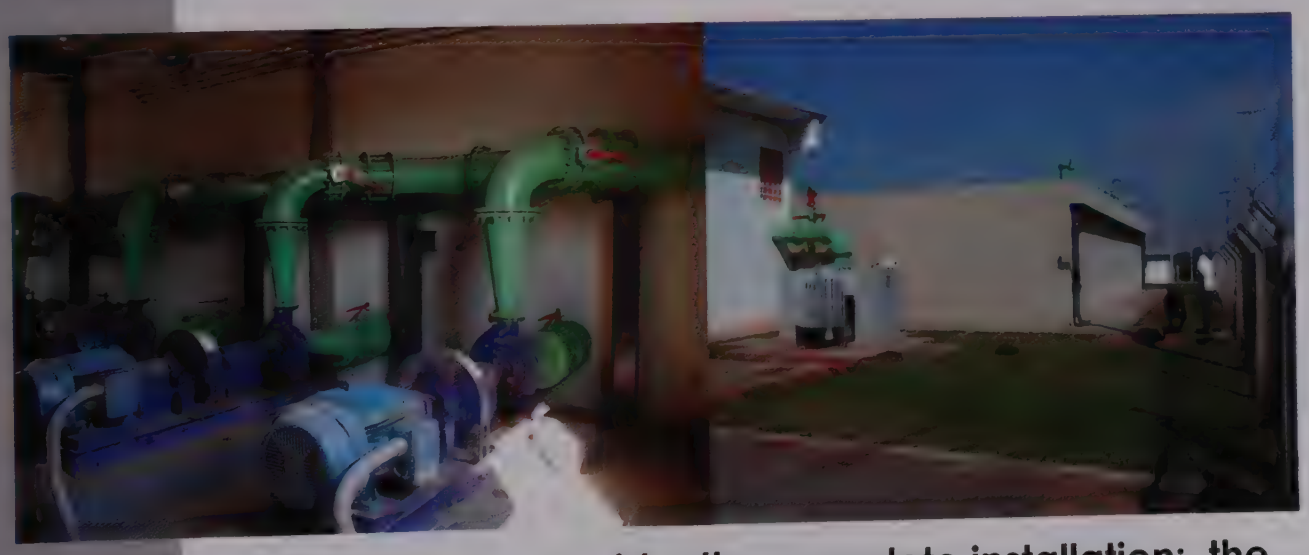
Installation is not just the nearest fitting



Make sure you consider the complete installation: the suppliers 10D is used here.

look how many fittings should have been considered: 15 are upstream of meter within a total of 25 diameters!

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Cooling Water Application: Brazil 26/10/06

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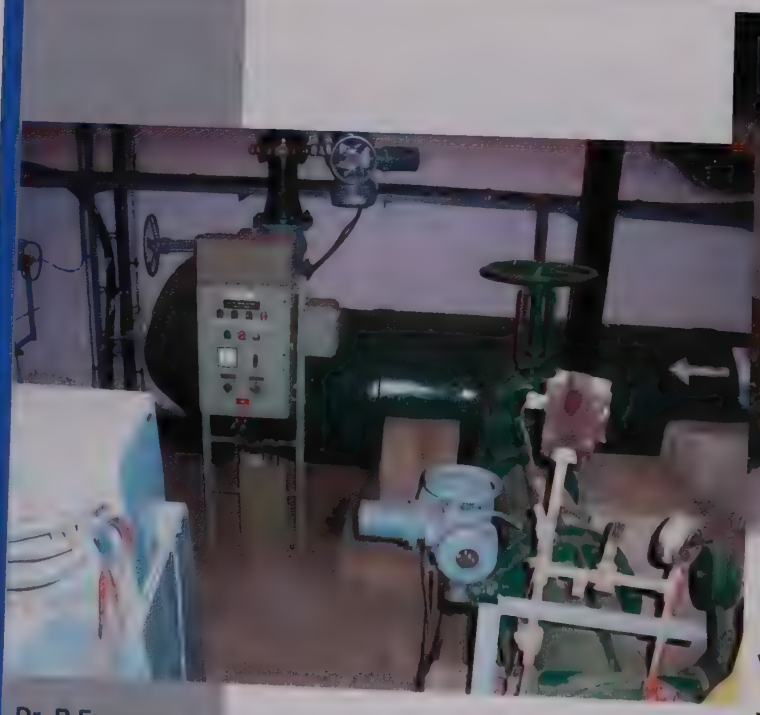
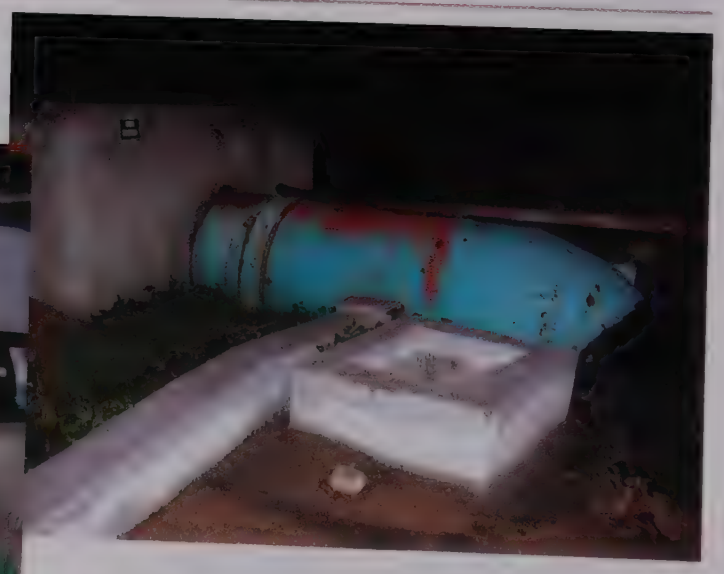
Example of poor suppliers advice: Jamshedpur





In this installation meter is within 3D of a bend and with four other fittings all within 10D

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Water Supply Flow Measurement – Presentation Overview

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- Requirements for measurement
- General methods applicable
- Fluid flow considerations
- **Installation effect factors**
- Errors expected
- Recommendations for supply management

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Types of Installation Effects

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Fluid dynamic	Velocity profile effects Presence/generation of swirl Presence of fluid pulsations Presence of multiple phases Fluid property effects of process site
Mechanical	Poor siting of fittings Fitting combination effects Influence of valves Pipe roughness/deposition Use of conditioners/filters
Other effects	Ambient temperature Local RFE/EMI present Pipe vibration Local humidity effects

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Large Pipe Flows, Libya N. Africa

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Pump Station Tests, Tarhunah, Libya

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Pumps 4,5,7 and 8: 3.5 m^3/s +/- 3.2%

Pumps 1,3,5 and 7: 3.65 m^3/s +/- 3.9%

Pumps 1,2,5 and 6: 3.35 m^3/s +/- 1.95%

Pumps 1,2,7 and 8: 3.5 m^3/s +/- 3.0%

Pumps 2,3,6 and 7: 3.55 m^3/s +/- 2.7%

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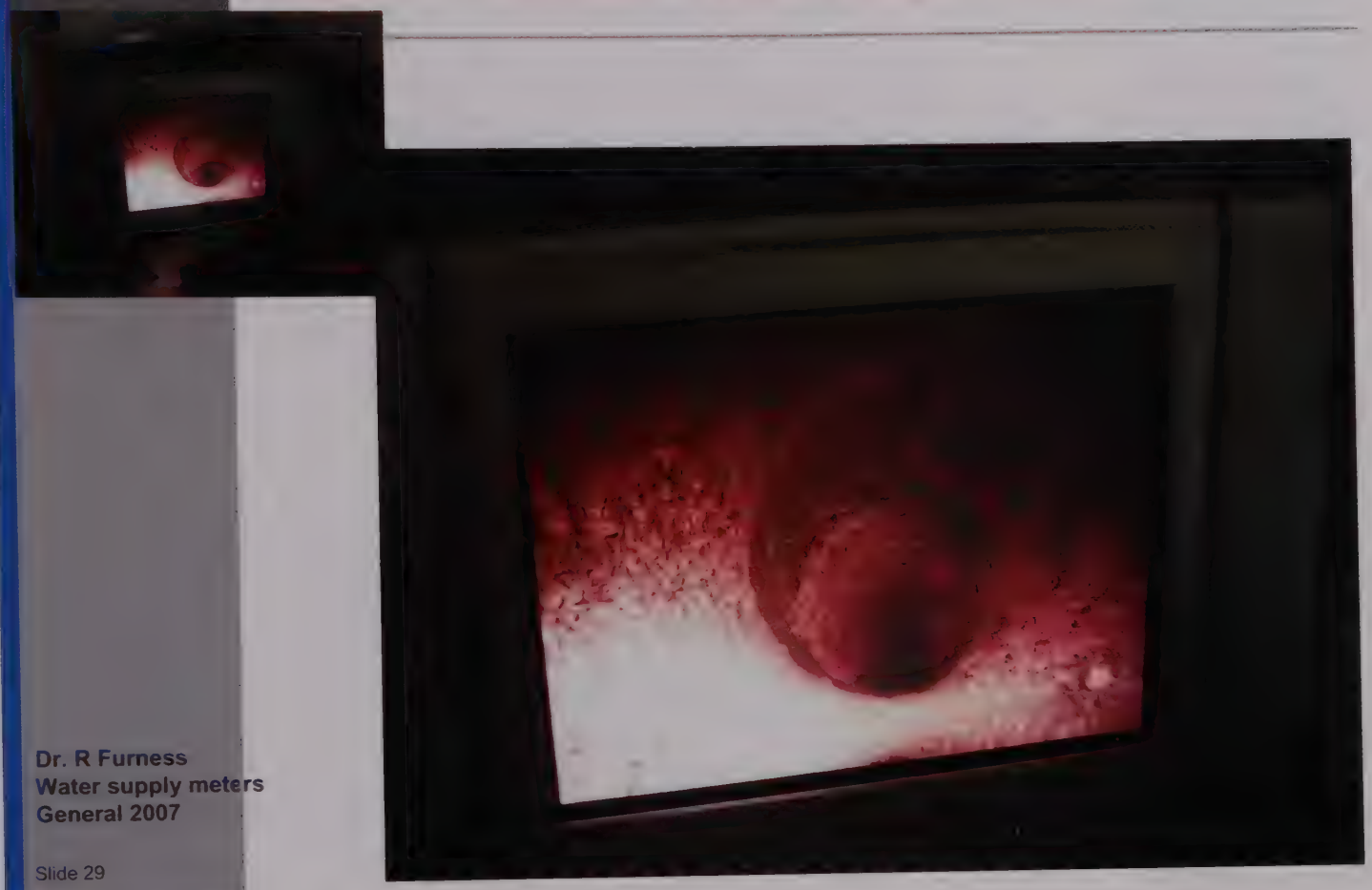
Inside of 102 Year Old USA Supply Main



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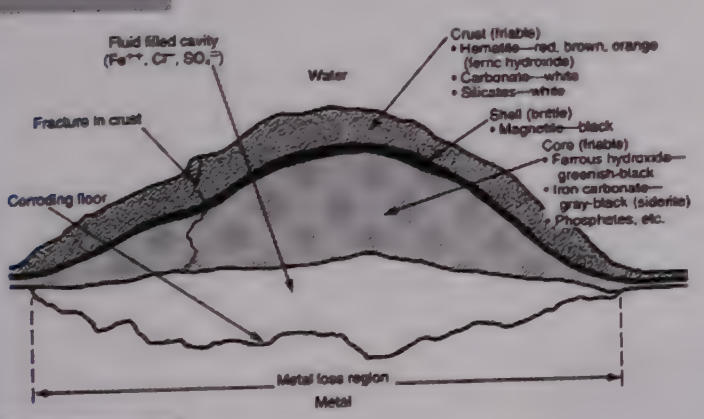
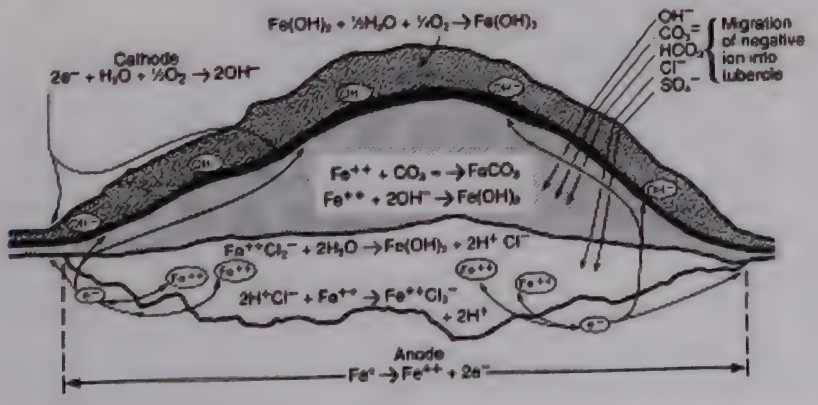
Tuberculation in pipes



Water pipes have all the ingredients for tuberculation: low flows, chlorine, dissolved oxygen, water and metals



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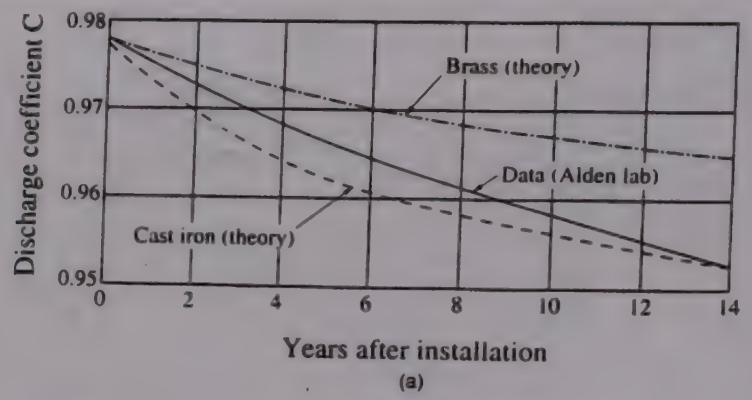
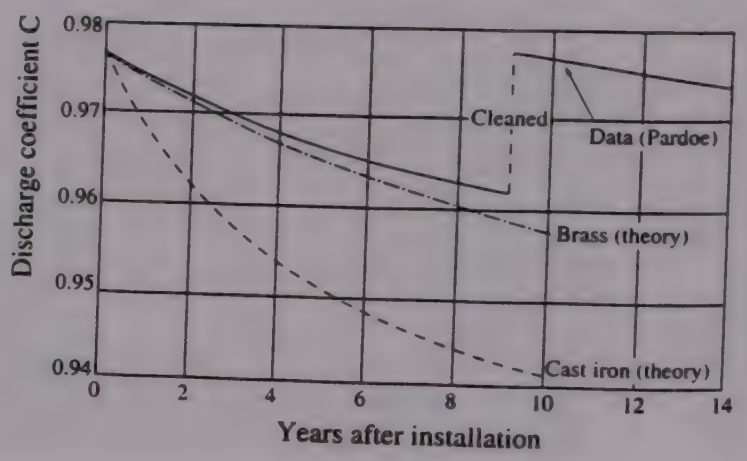
Time Dependent Trends Seen in Venturi Meters



(a)



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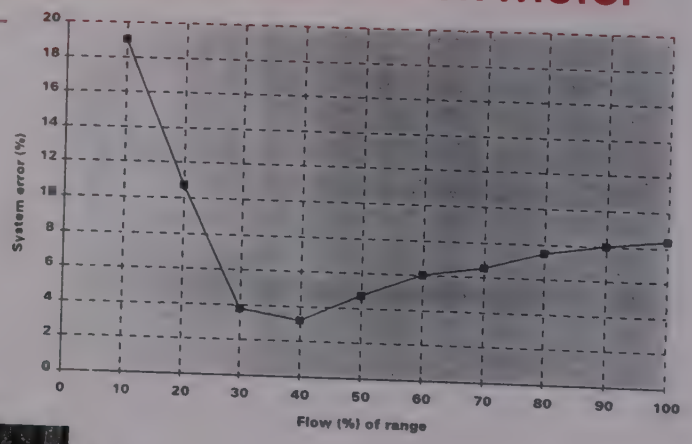
Measured Errors in a Sedimented Venturi Meter



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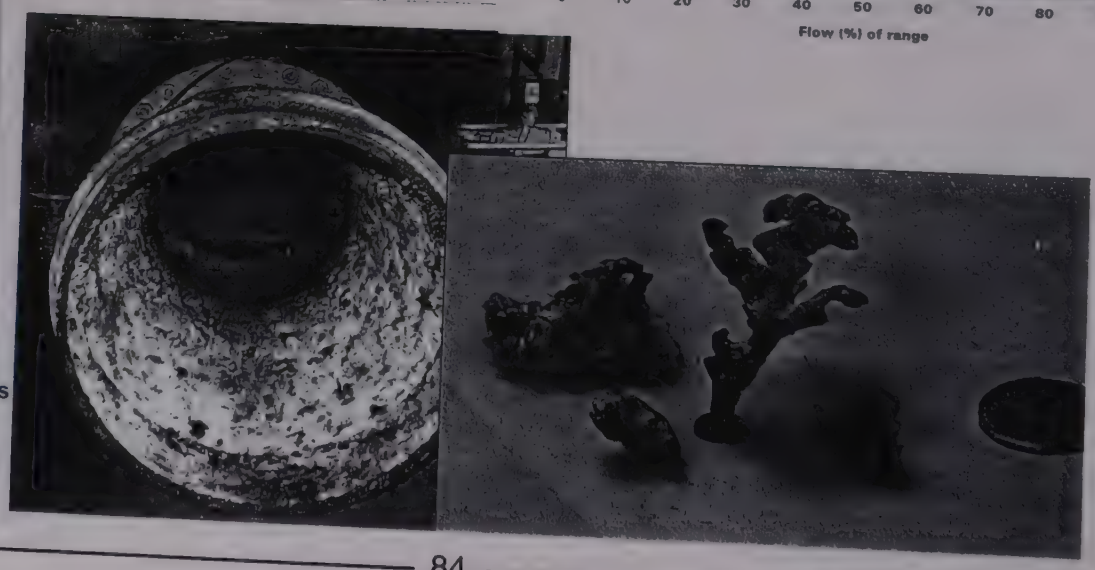

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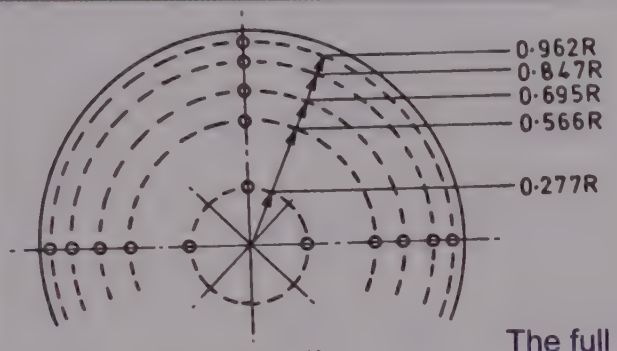
Estimation of uncertainty using velocity probes



Positions for 10 point traverse

$$U = v_0\left[\frac{5}{12}r_1^{*2} - \frac{1}{12}r_2^{*2} + \frac{1}{12}\frac{r_1^{*2}}{r_3^{*}}\right] +$$

$$+ v_1\left[\frac{1}{6}r_1^{*2} + \frac{2}{3}r_2^{*2} - \frac{1}{12}r_3^{*2}\right] -$$

$$- v_2\left[\frac{1}{12}\frac{r_1^{*2}}{r_3^{*}}\right] +$$

$$+ \sum_{i=2}^{i=n-2} v_i\left[-\frac{1}{12}r_{i+2}^{*2} + \frac{2}{3}r_{i+1}^{*2} - \frac{2}{3}r_{i-1}^{*2} + \frac{1}{12}r_{i-2}^{*2}\right] +$$

$$+ v_{n-1}\left[\frac{1}{2}r_n^{*2} + \frac{1}{12}r_{n-1}^{*2} - \frac{2}{3}r_{n-2}^{*2} + \frac{1}{12}r_{n-3}^{*2}\right] +$$

$$+ v_n\left\{\frac{m}{m+1}(1 - r_n^{*2}) + \frac{1}{12}\frac{(r_n^{*2} - r_{n-1}^{*2})^2}{m(1 - r_n^{*2})} + \right.$$

$$\left. + \frac{7}{12}r_n^{*2} - \frac{2}{3}r_{n-1}^{*2} + \frac{1}{12}r_{n-2}^{*2}\right\}.$$

The full formula using the Method of Cubics is very complex, with much uncertainty. Each local velocity has an uncertainty and these are compounded in the overall calculation.

Do not expect good accuracy!!

Flowrate Calculation From Profiling

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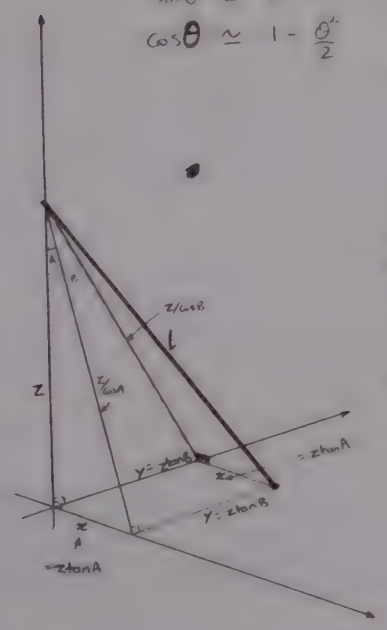
Possible Errors Arising From Insertion Sensors

for small θ (radians)

$\sin\theta \simeq \theta$

$\cos\theta \simeq 1 - \frac{\theta^2}{2}$



$x = z\tan A$

$z = \frac{L\cos A}{\sqrt{1 + \cos^2 A \tan^2 B}}$

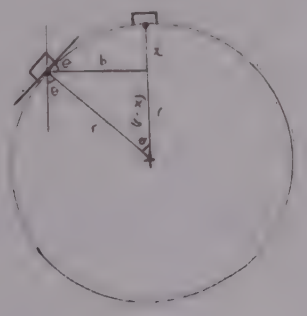
radial dist $= \sqrt{(T - z^2) + x^2}$

(iii) Mis aligned in x-y and y-z plane.

if mis alignment angle in x-y plane = β
& mis alignment angle in y-z plane = α
& insertion depth = d

then corrected insertion depth $d_c = (d\cos\beta)\cos\alpha$

(x-y)	(y-z)	Pipe Bore (mm)	Insertion depth to d_c (mm)	Actual insertion depth (mm)	Error (%)
1°	1°	1000	500	499·85	0·03
5°	5°	1000	500	496·20	0·76
5°	10°	1000	500	484·92	3·02
-	5°	1000	500	498·02	0·40
1°	1°	1000	500	498·02	0·40



$r - (r\cos\theta) = x$

If 'r' is unknown

arc length $= r\theta$ (θ in rads)

final measurement $d_0 = d + x$ (if rad inclination = 0°)

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Water Supply Flow Measurement – Presentation Overview

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- Requirements for measurement
- General methods applicable
- **Fluid flow considerations**
- Installation effect factors
- **Errors expected**
- Recommendations for supply management

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Measurement basics: Venturi

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Example of installed uncertainty analysis: Philippines

1	Uncalibrated Venturi tube (depends on β ratio) but is in the range		1.0-1.5%
2	Calibrated Venturi tube	typically discharge coefficient known to	0.5%
3	Flow stability effects	typically in the range	0.5-2%
4	Approach pipe wall surface effects (depends on age) typically		0.2-03%/yr
5	Sedimentation effects at the upstream tap (age dependent)	typically	0.2%/yr
6	Sedimentation effects at throat tapping typically		0.1%/yr
7	Installation length deviations (inadequate upstream lengths)		1-5%
8	DP transmitter basic calibration uncertainty		0.1-0.2%
9	Ambient temperature effects		0.2-0.5%
10	Static and ambient pressure effects		0.2-0.5%
11	Telemetry, digitization and signal transmission effects		1%

Thus a 10 year old uncalibrated Venturi meter with no telemetry that is undergoing inspection and assessment may have an total uncertainty (U_{V10}) of say:

$$U_{V10} = \{(1.2)^2 + (1.5)^2 + (2)^2 + (2)^2 + (1)^2 + (0.2)^2 + (0.5)^2 + (0.5)^2\}^{1/2} = 3.65\%$$

(around 4%)

Where realistic values from the numbers 1,3,4,5,6,8,9,and 10 from the above table have been used. I have omitted an effect due to short installation lengths (7) as this would be a real case for one of the Lamesa meters after 10 years. If the analysis is repeated at 50 years (more typical of the real case at present), then the estimated uncertainty becomes:

$$U_{V50} = \{(1.5)^2 + (1.5)^2 + (10)^2 + (12.5)^2 + (5)^2 + (0.2)^2 + (0.5)^2 + (0.5)^2 + (1)^2\}^{1/2}$$

$= 16.95\%$ **(around 17%, very typical of many installations of this age around the world)**

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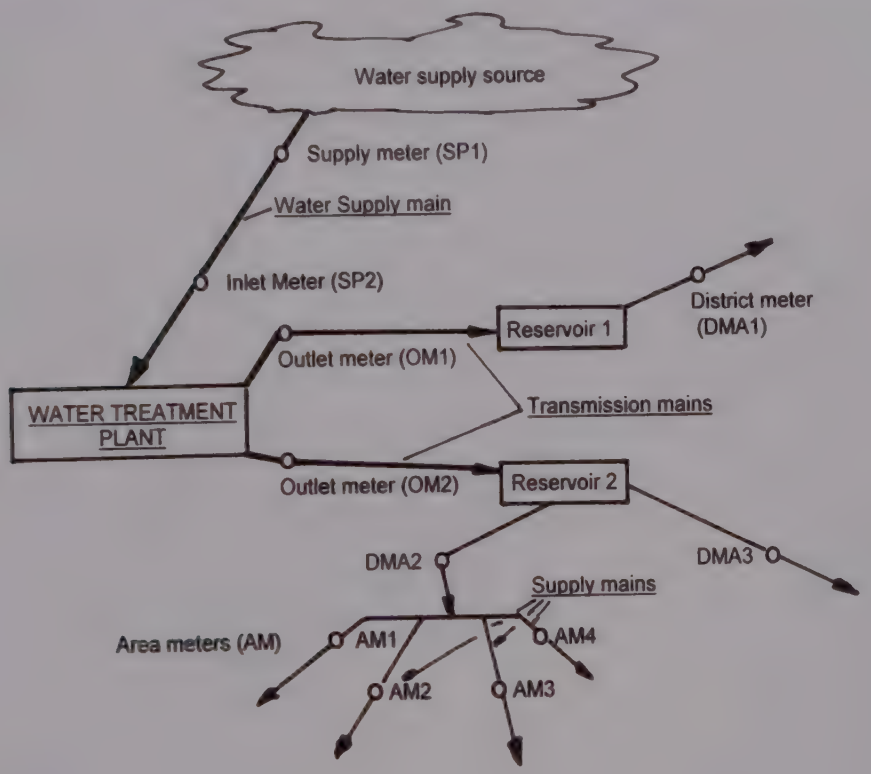
Example of simple uncertainty analysis - Brazil



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Worked uncertainty example – Actual flows

- Simple uncertainty analysis of the system in previous slide
- Inlets — Indicated flow — Uncertainty — Estimated flow range
- Meter SP1 — 1020 l/s — 2.3% — 1043.46 - 996.54 l/s
- Meter SP2 — 1011 l/s — 1.7% — 1022.12 - 993.81l/s
- Range of values: gain of 25.58 l/s (+2.5%) or loss of 49.66 l/s (4.89%)
- Average plant inlet = 1018 l/s
- Outlets
- Meter OM1 — 626 l/s — 5.3% — 659.18 - 592.82 l/s
- Meter OM2 — 375 l/s — 4.3% — 391.13 – 358.88 l/s
- Range of values: 1050.36 – 951.7 l/s (gain of 32 l/s or loss of 66 l/s)
- Balance in top section: gain of 57 l/s (5.5%) or loss of 116 l/s (11.3%)

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Cost of imbalance in Indian networks

- Assume water is sold locally for 26 rupees/m^3
- For a flow in 150mm pipe at 0.7m/s, the value is 26,000 rupees per day
- For 1% water loss this is 94,900 rupees/yr !
- For 2% loss in 300mm: value is 960,000 rupees/yr
- Imagine cost of 5% errors in 1000mm pipes
- MORAL: get best spec you can !!

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Reducing uncertainty

- Buy reputable equipment from reputable supplier
- Ensure meter spec is as good as required
- Ensure equipment is fully documented and calibrated
- Ensure calibration is accredited
- Ensure installation design contains no compound fittings
- Try to calibrate as the meter will be installed
- Ensure the meter is regularly checked and maintained

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Fully Traceable Primary Flow Calibration

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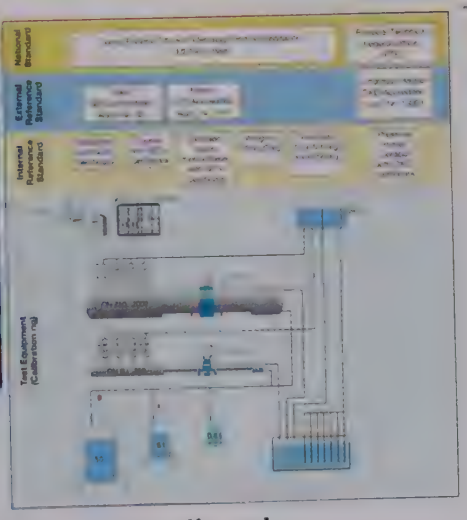
Calibration Standards for All Flowmeters



ISO 4185 (1980)	Gravimetric - International
ISO 8316 (1987)	Volumetric – international
ISO 7278	Pipe provers - fiscal
ISO 7066 (1997)	Uncertainty
ISO 17025 (1999)	Competence and documentation
ISO 9104	is not a calibration standard it is a test protocol for suppliers to meet their own specs

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Water Supply Flow Measurement – Presentation Overview

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- Requirements for measurement
- General methods applicable
- Fluid flow considerations
- Installation effect factors
- Errors expected
- **Recommendations for supply management**

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Ideal Network Management Flowmeter

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Magnetic meters are world standard for <1000mm pipes

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Flow

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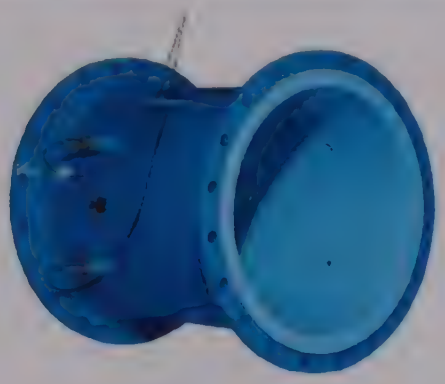
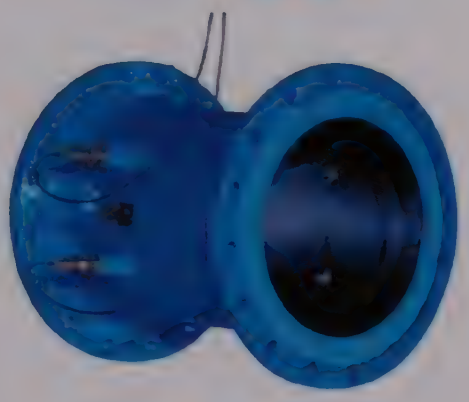
In-line calibrated spool pieces





Measuring tube:

- Size range: DN300...2000
- Pressure rating: PN6,10,16, AWWA, ANSI Class 150 lbs sensors
- Temperature range -10...+60°C
- Material: St. 37.2 epoxy coated, suitable for:
- Drinking water
- Waste water

Optimised for water supply applications: cost effective in line sizes above 1000mm

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Flow

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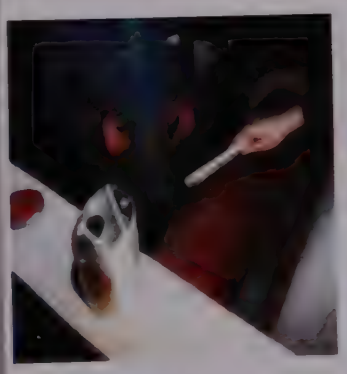
Insertion type sensor installation



1. Mark

2. Cut

3. Align

4. Weld

Only option for lines that cannot be shut down

Ideal for retro fitting

For new installations errors are introduced from day 1

These appear in marking, cutting alignment and welding and are larger than is realised

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Technical presentation - flowmeters

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- Drawing up the specification

ENQUIRY NO. ..... COMPANY .....
DATE ..... ADDRESS .....
TEL .....
FAX .....
CONTACT NAME .....

1. PROCESS CONDITIONS
Flowrate (Litres/min) min: ..... normal ..... max .....
Fluid .....
Pressure (bar) min ..... normal ..... max .....
Temp (°C) min ..... normal ..... max .....
Density (kg m³) ..... Viscosity .....

liquid ☐ gas ☐ two-phase ☐

Abrasive yes ☐ no ☐ corrosive yes ☐ no ☐

Wet gas yes ☐ no ☐ dirty liquid yes ☐ no ☐

Flow pulsations yes ☐ no ☐ outside installation yes ☐ no ☐

2. APPLICATION CONSIDERATIONS

Batch process yes ☐ no ☐ Flowrate Constant yes ☐ no ☐

Accuracy required <0.5% ☐ <1% ☐ <2% ☐ <5% ☐ >10% ☐

Volume flowrate ☐ Mass flowrate ☐ Quantity passed ☐

Units required .....

3. INSTALLATION CONSIDERATIONS

Line Size ..... Pipe material .....
Straight pipe lengths available (pipe diameters)
Upstream ..... Downstream .....

Bends upstream yes ☐ no ☐ If yes, how far .....

Pump upstream yes ☐ no ☐ If yes, how far .....

Line horizontal ☐ Line vertical ☐
Inclined ☐

4. OTHER FACTORS

Power available no ☐ 24VDC ☐ 110V ☐ 240V ☐

Power sources near flowmeter yes ☐ no ☐

Risk of freezing yes ☐ no ☐

Access for servicing restricted ☐ poor ☐ good ☐

Output required 4-20 mA ☐ pulse ☐ other ☐

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Summary of flowmeter accuracy

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Factors that affect installed performance

- Total uncertainty of meter tested in lab **plus**
- Uncertainty due to site pipework **plus**
- Uncertainty of any external influences **plus**
- Uncertainty from changes in fluid effects **plus**
- Uncertainty for any pipe sedimentation **plus**
- Data conversation and transmission effects **plus**
- **Plus ???**

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- Even if basic meter calibration was 0.25-0.3% - a total installed uncertainty of 1-2% is not unreasonable

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Meters Technology and Choice for Networks

- Choice is always a compromise
- Magmeters give best accuracy
- Mechanical meters usually used in lines <50mm
- Line sizes 100-1000mm mags are best overall and on cost
- Lines 1000-2000mm ultrasonics are recommended (cost lower but accuracy worse)
- Use 2 or more paths meters for lines above 1000mm and calibrated spool pieces are preferable
- Be very careful when using insertion type meters: accuracy is usually not good and worse than supplier says. Real positional errors now being analysed

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With Best Compliments from

Arghyam

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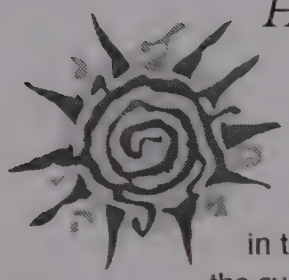
quick facts on...

50 Ways To Be Water Smart

How you can help save limited water supply



Saving Water Outdoors

1. Don't overwater your lawn – no more than once a week in the winter or twice a week in the summer. A good rain eliminates the need for watering for up to two weeks. Buy a rain gauge. Most of the year, lawns only need one inch of water per week.

2. Plant it smart. Xeriscape landscaping is a great way to design, install and maintain both your plants and irrigation system. It will save time, money and water.

3. Water lawns during the early morning hours when temperatures and wind speed are the lowest. This reduces evaporation and waste.

4. Position sprinklers so water lands on the lawn and shrubs and not on paved areas.

5. Install irrigation devices that are the most water efficient for each use. Micro and drip irrigation and soaker hoses are examples of efficient devices.

6. Check sprinkler systems and timing devices regularly to be sure they operate properly. Florida law now requires that "anyone who purchases and installs an automatic lawn sprinkler system MUST install a rain sensor device or switch which will override the irrigation cycle when adequate rainfall has occurred."

7. Raise the lawn mower blade to at least three inches, or to its highest level. A higher cut encourages grass roots to grow deeper, shades the root system and holds soil moisture.

8. Avoid over fertilizing your lawn. Applying fertilizer increases the need for water. Apply fertilizers which contain slow-release, water-insoluble forms of nitrogen.

9. Use mulch to retain moisture in the soil. (Help preserve native cypress forests by selecting other types of mulch such as treated melaleuca.) Mulch also helps control weeds that compete with landscape plants for water.

10. Plant native and/or drought-tolerant grasses, ground covers, shrubs and trees. Once established, they do not need water as frequently and usually will survive a dry period without watering. They also require less fertilizer or herbicides. Group plants together based on similar water needs.

11. Use a broom or blower instead of a hose to clean leaves and other debris from your driveway or sidewalk.

12. Use a shut-off nozzle on your hose which can be adjusted down to a fine spray, so that water flows only as needed. When finished, turn it off at the faucet instead of at the nozzle, to avoid leaks. Check hose connectors to make sure plastic or rubber washers are in place. Washers prevent leaks.

13. Do not leave sprinklers or hoses unattended. A garden hose can pour out 600 gallons or more in only a few hours. Use a bell timer to remind yourself to turn sprinklers off.

14. Avoid purchasing recreational water toys which require a constant stream of water.

15. Consider using a commercial car wash that recycles water. If you wash your own car, park on the grass and use a hose with an automatic shut-off nozzle.

S A V E
W A T E R

16. Avoid installing ornamental water features (such as fountains) unless they use recycled water.

17. If you have a swimming pool, consider a new water-saving pool filter. A single backflushing with a traditional filter uses 180 to 250 gallons of water.

In Your Home

18. Never pour water down the drain when there may be another use for it. Use it to water your indoor plants or garden.

19. Make sure your home is leak-free. Check your water meter when you are certain that no water is being used. If the meter reading changes, you have a leak!

20. Repair dripping faucets by replacing washers. One drop per second wastes 2,700 gallons of water per year!

21. Retrofit all household faucets by installing aerators with flow restrictors.

22. Check for toilet leaks by adding food coloring to the tank. If you have a leak, the color will appear in the bowl within 30 minutes. (Flush immediately to avoid stains.)

23. If the toilet handle frequently sticks in the flush position, letting water run constantly, replace or adjust it.

24. Install a toilet displacement device to cut down on the amount of water needed for each flush. (Don't use a brick! There are devices available at most hardware and home centers.) Be sure installation does not interfere with the operating parts. Consider low-volume toilets which use less than half the water of older models. NOTE: In many areas, low-volume units are required by law.

25. Take shorter showers. Replace your showerhead with an ultra-low-flow version.

26. Place a bucket in the shower to catch excess water to water plants.

27. In the shower, turn water on to get wet; turn off to lather up; then turn the water back on to rinse off. Repeat when washing your hair.

28. Operate automatic dishwashers and clothes washers only when they are fully loaded or set the water level for the size of load you are using.

29. When hand washing dishes, save water by filling two containers – one with soapy water, one with rinse water containing a small amount of chlorine bleach.

30. Store drinking water in the refrigerator. Don't let the tap run while you are waiting for water to cool.

31. Do not use running water to thaw meat or other frozen foods. Defrost food overnight in the refrigerator, or use the defrost setting on your microwave.

32. Kitchen sink disposals require lots of water to operate properly. Start a compost pile as an alternate method of disposing of food waste.

33. Do not waste water waiting for it to get hot. Capture it for other uses such as plant watering or heat it on the stove or in a microwave.

34. Consider installing an instant hot water heater on your sink and insulating your water pipes.

35. Think twice about installing a water-to-air heat pump or air-conditioning system. Newer air-to-air models are just as efficient and do not waste water.

36. Don't let water run while brushing your teeth, washing your face or shaving.

37. Install water softening systems only when necessary. Turn softeners off while on vacation.

38. If you have a well at home, check your pump periodically. If the pump kicks on and off while water is not being used, you have a leak.

39. Avoid flushing the toilet unnecessarily. Dispose of tissues, insects and other similar waste in the trash rather than the toilet.

General Water Saving Tips

40. Follow water conservation guidelines and ordinances in your community. Even if your water comes from a private well – you are expected to comply.

41. Report water losses (broken pipes, open hydrants, errant sprinklers, abandoned free-flowing wells, etc.) to the property owner, local authorities or your water management district.

42. Promote water conservation in community newsletters, on bulletin boards and by example. Encourage your friends, neighbors and co-workers to "be water smart."

43. Patronize businesses which practice water conservation, such as restaurants that only serve water upon request.

44. Encourage your employer to promote water conservation in the workplace.

45. Encourage your school system and local government to help develop and promote a water conservation ethic.

46. Support projects that will lead to an increased use of reclaimed waste water for irrigation and other uses.

47. Support efforts that promote water conservation among tourists.

48. Conserve water because it is the right thing to do – even when someone else is footing the bill, such as when you are staying at a hotel.

49. Participate in public water conservation meetings conducted by your local government, utility or water management district.

50. Try to do one thing each day that will result in saving water. Every drop counts!

Bangalore boom will be a doom - Without Water Conservation

M.N. THIPPESWAMY
Chief Engineer (Retd.), BWSSB

Synopsis

Bangalore city growth is alarming. City already has 7.0 million population and likely to grow by 9.0 million by 2015 as per the recent Bangalore Development Authority (BDA) projections. Providing water supply to the growing population is a Herculean task with the limited availability of fresh water resource. After implementation of Cauvery Water supply scheme (CWSS) IV Phase II, there is no availability of water from Cauvery source and also there is no nearby perennial fresh water resource. In view of limitation of fresh water source there is no way other than conserving the available water. There are number of means by which conservations measures could be implemented in order to meet the growing demand.

This paper deals with different measures, which the Bangaloreans must immediately take up on war footing for conservation of water.

Introduction

Bangalore city is located 980M above the sea level has celebrious climate throughout the year and because of which information technology and Bio-con technology have made big stride all over the world. There is a large influx of population from few decades and is still increasing in a very big way. Latest comprehensive development Plan (CDP) published by BDA indicates a development of 768 Sq. Kms., where in nearly 8.8 / 9.0 Million population by 2015. By 2025 it is estimated as 11.00 million population. The available infrastructure is quite inadequate such as water, sanitation, roads, electricity etc. Particularly water is going to be most crucial and a scare resources among the infrastructure requirement for the growth of Bangalore city.

Bangalore Water Supply and Sewerage Board was formed in the year 1964 mainly to provide and augment water supply and sewerage facilities for the growing population and realisation of revenue. Board has implemented CWSS Stage I , II, III, IV Phase I in a span of 40 years, which means each decade one scheme of Cauvery has been implemented to meet the growing population demand. Since city is located 980M above sea level and all the surface sources are far away, it is a very costly process to implement each scheme. The latest scheme CWSS IV Phase II is likely to cost Rs.4000 crores to bring additional 500 MLD of water. Thus with a huge capital cost and maintenance cost is incurred in order to bring additional water supply to Bangalore city. By implementing these scheme the total 1450 MLD (which is equal to 600 cusecs) will be conveyed from Cauvery source. In addition there are more than one lakh borewells with in BMA area and thus supplement about 200 MLD of water. But by 2015 the population projection of BDA indicates about 9.0 million and considering the prevailing losses in the distribution system, it would be very difficult to meet even the prevailing per capita supply.

Hence it is quite evident that BWSSB and the residents of Bangalore must start for conservation from right now.

Present water supply status:

The city get about 860 MLD (Million Liter Per Day) of water from both Cauvery and Arkavathy source. More than 95% of water is supplied from Cauvery source. From last more than 10 years the dependability of Arkavathy source has come down drastically and now it is only about 10% dependable because various reasons in catchment. Probably in next few years, these sources may become redundant.

Name of the source	Year of construction	Potential yield	Present drawl
Hesaragatta source	1896	36	4
T.G. Halli, CRS scheme	1933 - 62	148	40
CWSS I	1974	135	135
CWSS II	1982	135	135
CWSS III	1993	270	290
CWSS IV Phase I	2002	270	270
CWSS IV Phase II	2006 -2013	500	–

At present about 5.0 Million population is served with the present inflow from the above sources, which includes entire BMP area part of CMC area and a few industrial areas outside CDP.

Population projection and Demand

As per 2001 censes the population within BMA area is 6.0 million of which 4.5 million within BMP and about 1.5 million in rest of the CDP area and mainly in CMC area. As per latest CDP, the projection of population will be 8.8 million by 2015 and 10.1 million by 2021 in an area of 786 Sq. Kms. Bangalore Water Supply and Sewerage Board is responsible for providing water supply and sewerage facilities in to BMA areas by augmenting new schemes to the growing population. Recently, BWSSB has provided water supply and sewerage facilities for all the 100 wards of BMP and these areas are being provided for water supply facilities particularly in newly added 27 wards of BMP. In addition BWSSB has already awarded work of providing water supply facilities in 7 CMC and 1 TMC and these works are fast progressing. The area covered is about 228 Sq. Kms., and population of nearly 2.0 million.

	1991	2000	2010	2020	2025
High growth (in Lakhs)	48.37	64.68	85.05	106.41	118.28

* Above table is based on AusAID Master Plan report considering the per capital supply to be provided as per CPHEEO norms (150 LPCD), it would require about 1700 MLD, which includes domestic and industrial etc.

Fresh water resource availability

By implementing CWSS IV Phase II, BWSSB will fully utilize its allocation of 600 cusecs i.e. 1450 MLD from Cauvery source. Beyond this quantity, water is not available in Cauvery river after meeting the mandatory releases to the neibouring state. However, BWSSB / GOK has sought additional allocation from Cauvery tribunal to an extent of 35 TMC. After implementation of above scheme BWSSB will utilize 19 TMC and beyond this quantity unless a storage facility is made exclusively for BWSSB requirement, no additional water will be available except during mansoon period. But construction of additional storage capacity after obtaining necessary approval will take a lot of time and also funds for implementation of the scheme. But there is no immediate solution even to bring any fresh water from any of the tributaries of Cauvery such as Hemavathi, Harangi, Kabini etc. These schemes will also costs more than the present scheme but ultimately no availability of water in these sourcess. But before we look at other perennial sources, it is absolutely necessary to immediately implement conservation measure, such as reducing the Un-accounted for water, rain water harvesting, recycling of wastewater for non-potable use and aquafier recharging etc to meet the additional requirement.

Presently the efforts made in conservation of water in Australian cities such as Sydney, Adelaide, Melbourne, Perth and also Singapore etc., and other American cities which are worth emulating.

Need for water conservation:

In view of the following reasons the conservation measures needs to be implemented on war footing.

1. Fresh water resources from Cauvery and other tributaries of Cauvery will not be available unless a storage reservoir is built exclusively for BWSSB requirement and this needs additional allocation from Tribunal.

2. The Bangalore city population is growing in alarming rate. The present population already reached 7.0 million and very shortly grows to 9.0 million.

3. The ground water potential is dwindling. The present water table is receding at a alarming rate because of extraction is more than the recharge. The water table is reducing by 2 meters every year. Many areas of CDP are under dark zone as per satellite imagery, where the underground water source is absolutely poor.

4. Individual and public places harnessing rainwater is not made compulsory.

Conservation Measures:

In order to augment water to the growing population conservation measures noted below need to be taken up in priority.

1) Reduction of Un-accounted water:

Through BWSSB is pumping about 860 MLD of water only 60% of water is billed and rest is lost in distribution system. There is a loss of nearly 40% water (non Revenue wster), which is brought to the city. In many of the developed countries the loss in the distribution is less than 10%, but for a well-managed system up to 15% is accepted. If the loss can be brought down to 15, more than 215 MLD of fresh water can be saved. This has the following benefit such as

a) Saving precious fresh water

b) Saving in additional maintenance cost such as power, chemical etc.

c) More water available for augmenting additional population.

d) Improvement in BWSSB finances

BWSSB has incidentally taken up pilot project to reduce the UFW. But this has to be globalised for entire Bangalore city. This project has to be taken up on top most priority.

Phase I – 18 months – establishing DM, Leak detection, Pipe repair / rehabilitation.

Phase II – 18 months - monitoring and maintaining target UFW levels 270 KM's distribution network in Central parts of the city serving 35000 connections UFW reduction and control trategy & methodology by Themes water. Distribution network rehabilitation by L & T

Cost of the project Rs.480 million

No of DMA's – 16

2) Recycling of wastewater:

More than 800 MLD of wastewater is now discharged in to river basins namely Cauvery and Ponniar. BWSSB is now bring fresh water from a distance of 100 Kms., for a head of 500m. Each MLD of water cost Rs.7.00 cores of capital cost. But the wastewater is discharged after secondary treatment. In view of scarcity of water, it is absolutely essential re-use this wastewater for different application such as agriculture, Industrial, recreational use, non-potable use including dual water supply system for new layouts. By introducing one more degree of treatment i.e. advanced treatment, it is possible to use for many applications such as air-conditioning, cooling, toilet fleshing, gardening, car washing etc., for both industrial and domestic application. Many cities in Australia, USA, Japan, Israel and some cities in Middle East are regularly following this technology.

BWSSB has already built two recycling plants of 60 MLD and 10 MLD capacities at Vrishabhavathy and Yelahanka treatment plants respectively. In addition golf course at Bangalore golf club and Karnataka Golf Club have built 1.0 MLD and 1.5 MLD recycling plant for lawn irrigation. Similarly in Cubbon park a plant of 1.5 MLD with MBR technology has been installed for catering to Cubbon park, Vidhana Soudha, Rajbhavan garden requirement. However, the trend has set for recycling wastewater for non potable use. Similar capacity plants need to be installed at different requirement of industries such as Soft-ware industries, big housing complexes and where fresh water requirement is not necessary required.

BWSSB has plans to install few more plants in Hosur road along international Air Port and also near ITPL where there is a demand from industries etc.

As per the studies conducted by many agencies around the World, the average water utilized in any country for a domestic purpose nearly 60% of water is used for toilet, lawn, car cleaning, washing etc., and only 40% of water is used for drinking, cooking and other requirements. Considering this many cities where fresh water resource is very scare, dual water supply system has been adopted. Dual water supply system

exists more than a century in North America. Many of the cities in Australia such as Sydney, Adelaide, Melbourne and Perth have already adopted dual water supply system. Similarly in North America many cities in California, Arizona, and Florida having from last three decades.

It is high time that Bangalore city should seriously implement dual water supply system in these new layout and insist for private layout for which sanctions are accorded by authorities concerned. This should be made mandate. However it stated by BDA that they would provide in their new layout such as Arkavathy layout, but invariably it should implement in all their new layouts. A policy paper should be brought out by BWSSB with regard to wastewater re-use and in particular dual water supply system.

Dual water supply system

Policy of BWSSB should indicate which are the areas that recycled to be used and what measures need to be taken to safe guard from using it for human consumption. It should also indicate to what extent wastewater to be recycled in a specified time frame.

Considering the non-availability of fresh water source the use of recycled wastewater should be taken up in all the Megacities for non potable use.

The concept of decentralized wastewater system, grey water treatment has already taken lead in many countries. By implementing smaller recycling plants the water can be utilized for the requirement for lakes and also for non potable uses such as parks, washing of roads, watering from road medians etc.

Rain water harvesting:

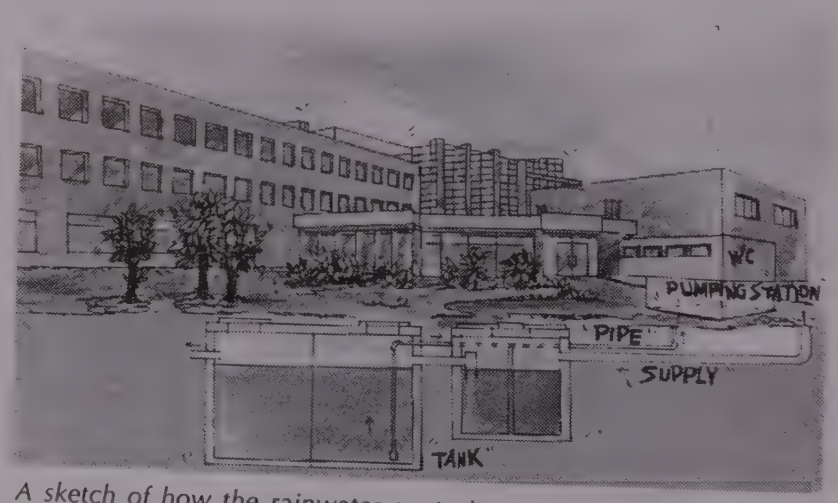
Rain water harvesting is not new, this is being practiced from 250 B.C. We can see this in Harappa and Mahenjadaro remains and also in many of old temples where big Vitharanas are built to store water during monsoon.

Rainwater harvesting can be taken up by individual houses, big housing complexes, industries etc., both in micro and macro level. By practicing rainwater harvesting at least three to four months in a year the requirement of water for non potable use can be met.

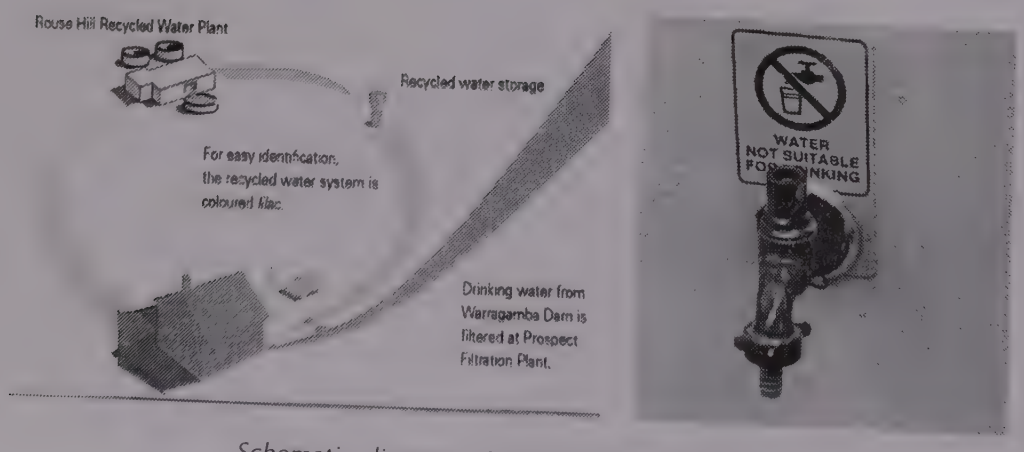
Now rain water harvesting is practiced in a big way not only in Indian cities and villages but also in many cities all over the World.

Recently in Chennai rain water harvesting has been made compulsory for of the existing and new houses. This aquafire recharges as well as availability of water for non potable use. Now many of the states are trying to follow foot prints of Chennai in view of big success.

By implementing this in Bangalore city also large quantity of water can be conserved. Here are some of the example of rainwater harvesting.



A sketch of how the rainwater capturing system works at German public buildings. Rainwater from the roof is taken to underground tanks via pipes. Here it is pumped to the toilets


Rouse Hill Recycled Water Plant
Recycled water storage
For easy identification, the recycled water system is coloured lilac.
Drinking water from Warragamba Dam is filtered at Prospect Filtration Plant.
WATER NOT SUITABLE
High quality water
Water processing unit

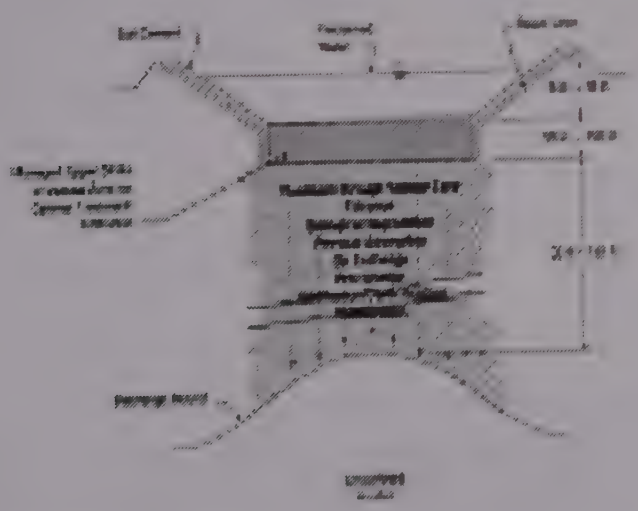
Schematic diagram of Sydney Rouse Hill housing complex where dual water supply was provided in 2000 and 2003 in two phases for a population of 3,00,000 residents is shown here.

Rain-water for rainy day practiced in Thailand

Aquifer Recharging:

Artificial ground water recharge with reclaimed water is an increasingly valued practices for augmenting potable water supplies. Artificial groundwater recharge can be accomplished by spreading in recharge basins or direct injections.

Recharge basins are the most widely used method of groundwater recharge. Recharge basins are shallow earthen ponds that contain treated water. Recharge basins are under laid with permeable soil that allows reclaimed water to infiltrate the soil surfaces and percolate through the vadose zone into the underlying aquifer. The supplemental treatment of reclaimed water that occurs during percolation through the soil and groundwater transport and storage is known as sol aquifer treatment. Figure highlights the elements of a soil aquifer system.



The preferred option for groundwater recharge is to either restore disused tanks and lakes and to construct new tanks where infiltration can occur over a long period of time. This work would need to be undertaken in conjunction with the BMP and would need to be a multipurpose facility which includes recreational facilities and parklands. The cost of these facilities would be depend on the details of the site selected

It is recommended that domestic, commercial and industrial rainwater harvesting tanks should have an overflow pipe discharging to a borewell or to a porous overflow pipe so that a maximum amount of recharge can occur. However there is no direct benefit to the householder or to the BWSSB and it is expected that few people will elect to provide this facility.

In Bangalore also this aquifer recharge should be practiced either through the recycled water or through storm water, in order to conserve and re-use at a appropriate time.

Water use Minimisation

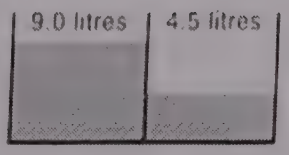
Installation of Water Meters : The demand management option of 100% metering of all domestic connections is already being pursued by the BWSSB for better management.

Metering of all connections will be an essential part in gaining the full benefit of future water price increases and some demand reduction. BWSSB has already taken up in a big way for metering even in slum areas by giving individual connections and also shared connections. Three pilot projects were implemented under AusAID Master Plan in Sudhamanagar, Chandranagar and Cement Huts slum areas.

Water minimization equipment

There are a range of water saving products that can be used in both domestic, commercial and institutions applications. These are now briefly mentioned. The use of this type of equipment will increase if community awareness improves in the coming years. The effects are likely to be small and may reduce domestic water bills in instance where conservation is practiced in individual households.

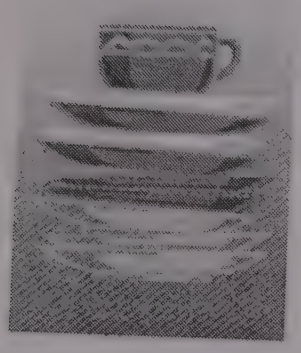
Dual Flush Toilets: Modern dual flush toilets that have a low volume flush and a higher volume flush use only 3 to 6 litres of water per flush and is one of the most effective ways to save water in the house. Older single flush toilets can use up to 10 litres of water for every flush. For a family of five, with each person using the home toilet twice daily, the savings would be of order 20,000 litres per year.

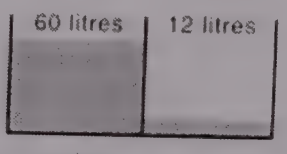


FLUSHING TOILET

Full flush	9.0 litres
Half flush	4.5 litres
Save	**4.5 litres**

By using a half flush for flushing liquid waste instead of a full flush, you can save 4.5 litres of water each time. For half flush, pull the lever and release immediately.





DISH WASHING

Washing under a running tap for 5 minutes	60 litres
Filled sink	12 litres
Save	**48 litres**

Simply by washing your dishes or vegetables in a filled sink, you can save up to 48 litres of water.

It is recommended that all new buildings and houses that provide flush toilets be required to provide dual flush units to obtain building approvals. Replacement units in existing buildings must also be dual flush units.

Water savings shower Heads and Timers: Modern shower heads use only 9 litres of water per minute compared to approximately 22 litres used by older showerheads. Savings would be approx., 20 KL per person per year.

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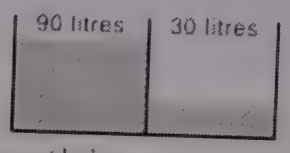
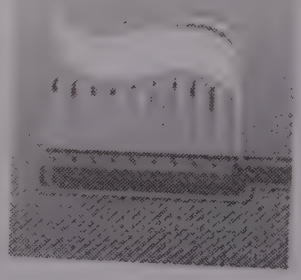
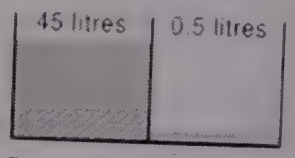


SHOWER

10-minute shower with the tap running	90 litres
10-minute shower with the tap off while soaping up	30 litres
Save	**60 litres**

By turning off the tap while you soap up or shampoo, you can save as much as 60 litres of water every time you shower.





BRUSHING YOUR TEETH

Tap running for 5 minutes	45.0 litres
Glass	0.5 litres
Save	**44.5 litres**

By using a glass to rinse your mouth, you can save up to 44.5 litres of water.

Timers can also be used to improve awareness of water consumption, particularly in large householders.

Drip Irrigation for Domestic and Institutional Gardens: Drip irrigation systems can be used to reduce runoff during garden watering. This may be more applicable to institutional garden watering using effluent re-use. It is a preferred option for agriculture irrigation.

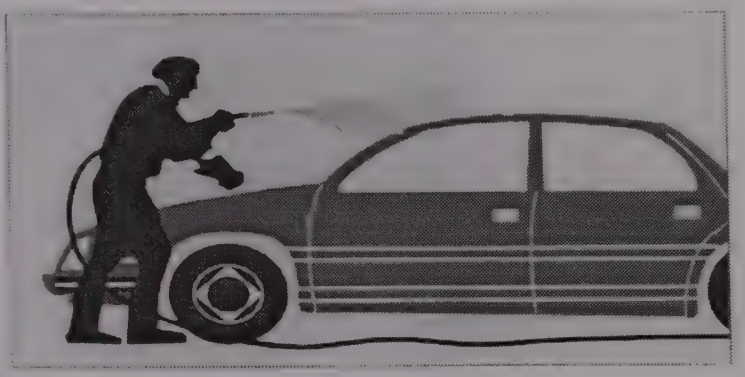
It is recommended that a community awareness campaign relating to the advantages of household water minimization equipment be introduced in the first five year period from 2006 to 2011. Proposals for development and implementation of a community awareness program are outlined in the SAP for Demand Management

Conservation measures to be strictly followed in order to conserve water within the household.

- If your toilet runs continuously, you have a leak. Stop the leak by adjusting the float and/or replacing tank components.
- To reduce the amount of water used by older toilets, place a plastic half-gallon container in the toilet tank. Fill with sand or small stones. This displaces water normally wasted during each flush.
- Repair all plumbing leaks. A slow drip can waste 10 to 25 gallons of water a day.
- The average shower uses five to 15 gallons of water each minute. Limit the time you spend in the shower and/or replace the older showerhead with a water-efficient, low-flow, showerhead.
- To reduce the amount of water used when showering: 1) wet your body, 2) turn off the shower while lathering, and 3) turn the shower back on to rinse.
- A short shower uses less water than a full bath. If you take a bath, fill the tub half way.
- Shutting off the water while shaving and brushing your teeth will save three to six gallons of water.
- Keep water in the refrigerator for drinking rather than running water from the spigot until it gets cold enough to drink.

Outdoors

- Wash your vehicle no more than once a week. If you wipe it off regularly, it will not need frequent washing.



- Don't water lawns and gardens more than necessary. Rather than follow a rigid schedule, watch for signs that plants really need water.
- Mulch gardens to retain moisture and keep down weeds.
- Water your lawn during the early morning or late evening hours to limit evaporation.
- Landscape your garden to use water efficiently and purchase plants that require less water for growth.
- Use a hose, with an automatic shut-off nozzle, for outdoor water activities.
- Don't use water to "sweep" sidewalks and drives. Use a broom or rake.

Conclusion:

Inspite of bringing additional water under CWSS Stage IV Phase II there is gong to be water scarcity beyond 2015. Further there is no planning for bringing additional water from any of the new resource. In absence this, unless water conservation measures are implemented immediately, Bangalore city is going to face acute shortage of water and will have impact on the growth of the city. All the above measures will take sufficient time for implementation by the Agencies concerned. Authorities concerned and the Government of Karnataka should take note of this and suitable measures should be taken to implement the following;

a) Reduce of unaccounted and non revenue water on war footing.

b) Recycling of waste water for all urban requirement including dual water supply systems by way of decentralized wastewater system.

c) Rainwater harvesting both in micro and macro level to be made mandate.

d) Conserving storm water and re-using by creating new resources close to the city.

e) Reducing wastage with in the plumbing system of each building by using highly efficient plumbing fixtures etc.

As the ground level is depleting alarmingly and no perennial fresh water resource available other than Cauvery, we have no other option other than implementing above conservation measures.

TURN IT OFF. DON'T USE WATER LIKE THERE'S NO TOMORROW.

Role of Modelling in Urban Water Networks – Quantity and Quality Issues

M S MOHAN KUMAR
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Extended Abstract

In any urban water network, there will be many connections involving pipes, pumps, reservoirs, valves etc connected in a complicated fashion. The challenge for a hydraulic engineer is to deliver water to a customer at an acceptable quality, in sufficient quantity and at reasonable pressure. Thus both the quantity and quality issues take an important role in the management of the system. These issues though look simple to address, will become a challenging task especially as the city grows in size and the network also under goes drastic changes, some times in an unplanned manner. Added to this, the levels of the terrain play a dominant role leading to high pressure / low pressure zones with leakages. Since many of the pipes in our distribution systems are very old especially in old distribution networks, they play a major role in its performance. Thus such a complicated network may naturally lead to the undesired results of nonequitable supply to different reservoirs / areas, undesirable leakages and deterioration in quality. Thus for proper management of an urban water network, various scenarios have to be evaluated before implementation of a good supply policy or alter the design of the existing system. Also the quality of the water, though of good quality at the treatment plant, may get affected due to the age and also the material of the pipe, especially in terms of the chlorine attenuation. Such issues could naturally be addressed using mathematical models

Mathematical models are powerful tools which try to depict the real world problems. In building or utilizing the already developed mathematical models one could simulate various scenarios and perform various simulations. An acceptable management policy could be chosen after sufficient search through these simulations. Some of these models are also used for quality prediction and also quality monitoring including transport of very hazardous contaminant through an early warning system. Also if the models are very powerful, they could also respond to real time control of the urban network with proper electro-mechanical support system

In this presentation various models, which address these issues will be discussed along with some successful field applications of modeling tools for better management of the system. The issues to be addressed are: use of mathematical models such as EPANET and other simple models, their utilization in proper representation and simulation of large urban network, addressing issues such as nonequitable supply, pressure build up / drop, leakage minimization, quality deterioration etc. These issues could also be addressed through models built around control algorithms. Many control algorithms and their merits and limitations in the control of an urban network will be discussed. Further, the use of mathematical models in tracing chlorine attenuation and contaminants in a network will also discussed through reaction modeling. Both chemical reaction and also the biological reaction on water quality and issues related to that would be addressed.

Simulation-optimization approach, which uses EPANET or some other simulator to provide the required simulated signals such as piezometric heads, velocities in pipes, chlorine concentrations and the optimization approach such as Gauss Newton method or stochastic based Genetic algorithm, is used for system parameter estimation / identification in terms of bulk / wall reaction coefficients, kinetic reaction rate, source strength identification to determine the rate / strength of chlorine injected..

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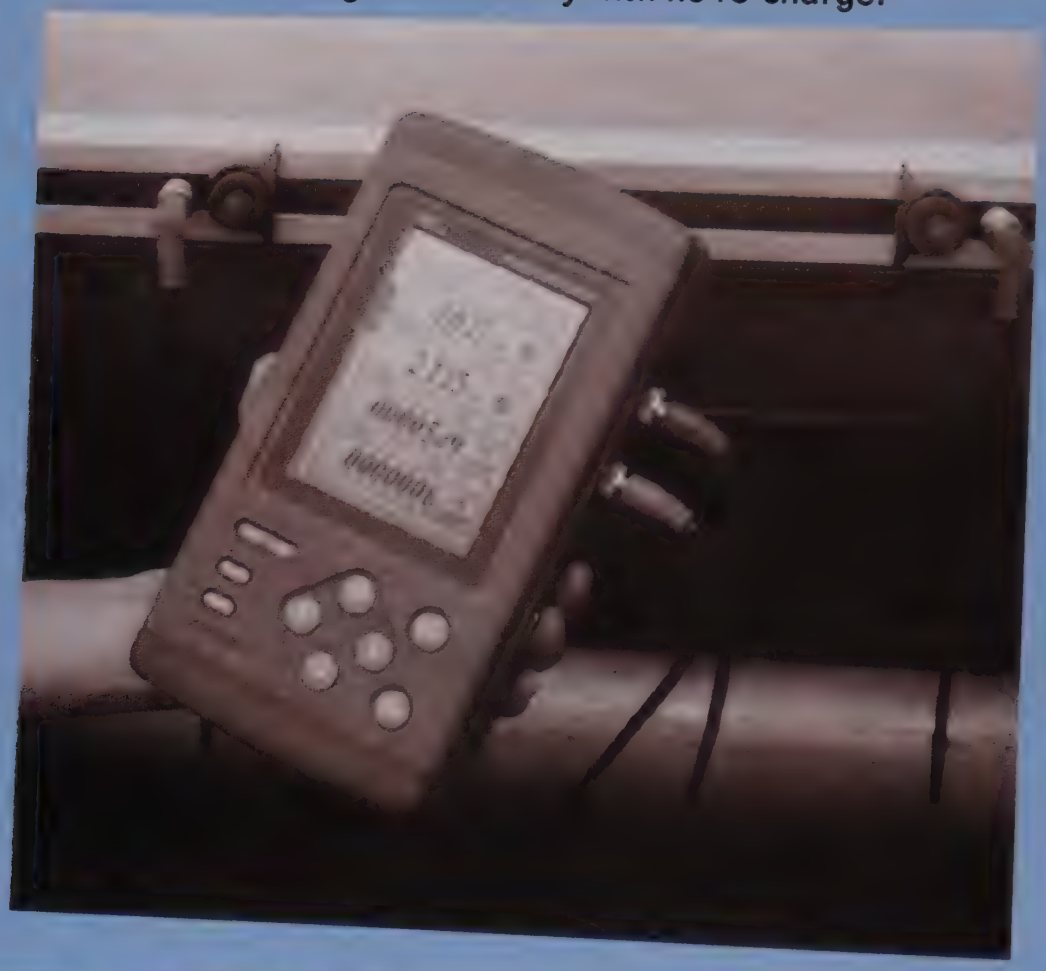

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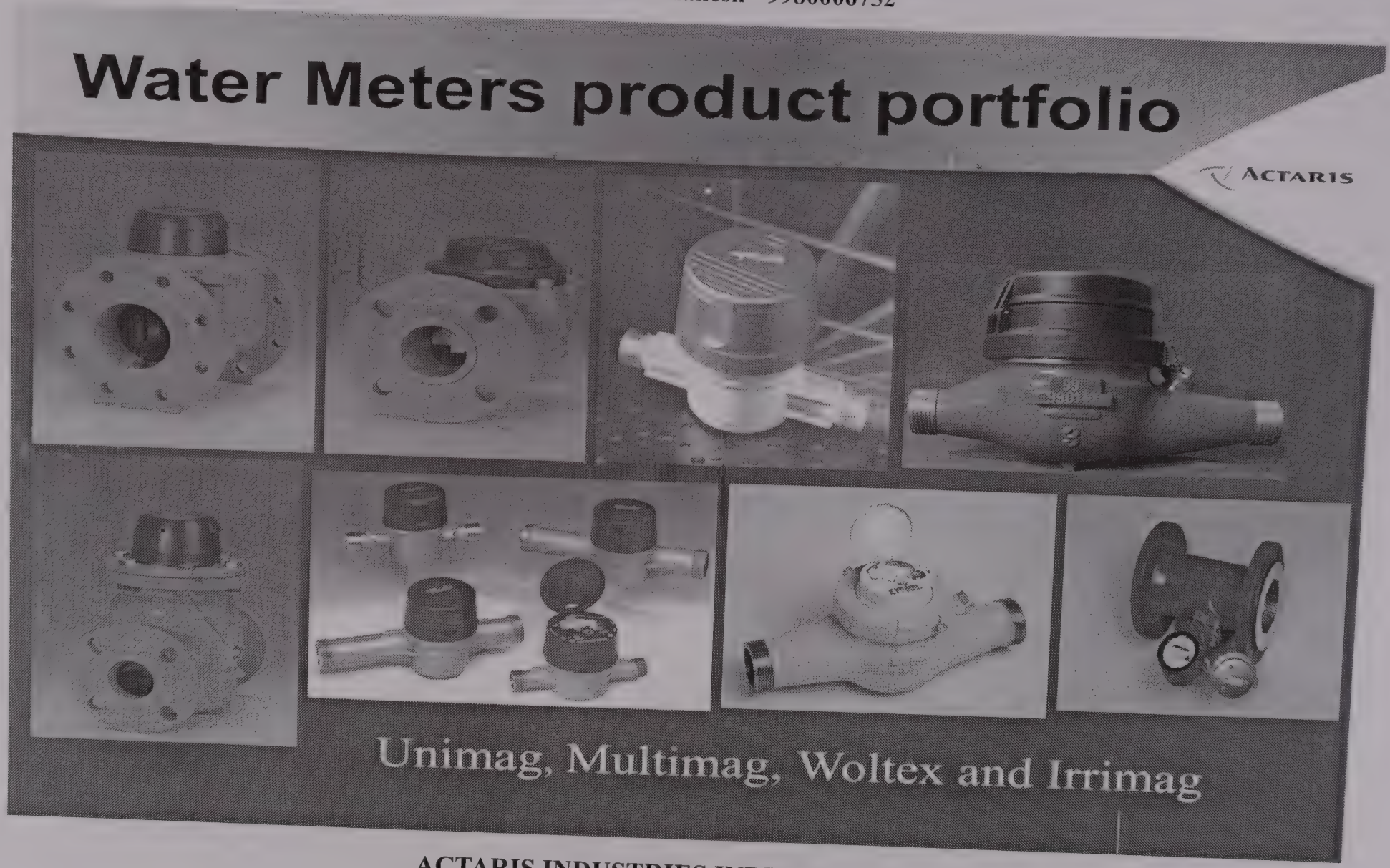

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